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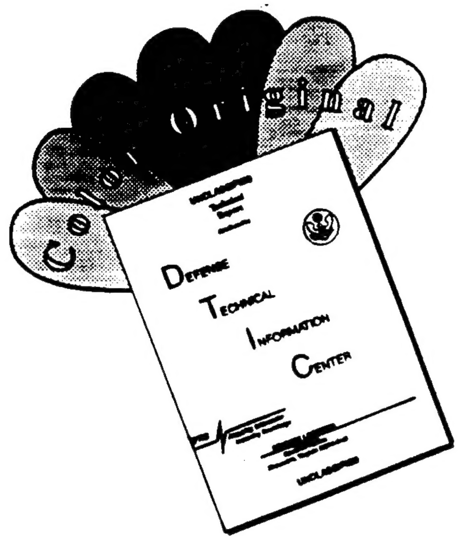

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THIS MONITORING PLAN WILL ALLOW ASSESSMENT OF THE PERFORMANCE OF THE EXTRACTION/RECHARGE SYSTEMS IN MEETING THE GOALS OF THE IRA AND WILL ALLOW COLLECTION OF SUFFICIENT DATA TO EVALUATE WHETHER OPERATIONAL CHANGES MAY BE NEEDED TO IMPROVE SYSTEM PERFORMANCE. THE MONITORING PROGRAM DESCRIBED IN THIS PLAN CONSISTS OF THE FOLLOWING PROCEDURES: INSTALLATION OF ADDITIONAL MONITORING WELLS, PERIODIC MEASUREMENT OF WATER LEVELS AND COLLECTION AND ANALYSIS OF WATER QUALITY SAMPLES BEFORE AND AFTER SYSTEM STARTUP, AND EVALUATION OF REPORTING OF MONITORING RESULTS TO ASSESS SYSTEM PERFORMANCE AND ALLOW OPERATIONAL ADJUSTMENTS.

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TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Draft Final Monitoring Plan for the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal Interim Response Action

February 1992
Contract Number DAAA15-88-D-0021/0001

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PREPARED BY

Harding Lawson Associates

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TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES iii

LIST OF PLATES iv

1.0 INTRODUCTION 1

1.1 INTERIM RESPONSE ACTION A 2

1.1.1 Purpose of Interim Response Action A 2
1.1.2 Design and Components of Interim Response Action A 2
1.1.2.1 First Creek Pathway 2
1.1.2.2 Northern Pathway 3
1.1.3 Schedule for Implementation 3

1.2 MONITORING PROGRAM OBJECTIVES 4

2.0 DATA USED IN THE DESIGN OF THE MONITORING PROGRAM 6

3.0 DESIGN OF THE GROUNDWATER MONITORING WELL NETWORK 8

3.1 CRITERIA FOR SELECTING ADDITIONAL MONITORING LOCATIONS 8

3.2 FIRST CREEK PATHWAY 9

3.3 NORTHERN PATHWAY 11

3.4 ADDITIONAL MONITORING WELLS 13

4.0 SAMPLING AND ANALYTICAL PROGRAM 15

4.1 BASELINE MONITORING 15

4.1.1 Water-level Monitoring 15
4.1.2 Water-quality Monitoring 16

4.2 OPERATIONAL MONITORING 16

4.2.1 Water-level Monitoring 16
4.2.2 Water-quality Monitoring 17

4.3 ANALYTICAL PROGRAM 17

5.0 EVALUATION AND REPORTING OF RESULTS 18

6.0 ACRONYMS AND ABBREVIATIONS 20

7.0 REFERENCES 22

LIST OF TABLES

Table No.		Page
3.1	Additional Alluvial Monitoring Wells to be Installed within the First Creek Pathway	9A
3.2	Additional Denver Formation Monitoring Wells to be Installed within the First Creek Pathway	9B
3.3	Additional Alluvial Monitoring Wells to be Installed within the Northern Pathway	12A
3.4	Additional Denver Formation Monitoring Wells to be Installed within the Northern Pathway	12B
4.1	Target Analytes for the Interim Response Action A Monitoring Program	17A

LIST OF FIGURES

Figure No.		Page
1.1	Locations of Extraction/Recharge Facilities and Contaminant Plumes	3A

LIST OF PLATES

Plate No.

1	IRA A Monitoring Well Network
2	Sampling Locations

1.0 INTRODUCTION

This plan describes the monitoring program to be implemented to assess the performance of the groundwater extraction and recharge portion of Interim Response Action (IRA) A the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal (RMA). This monitoring (1) will allow assessment of the performance of the extraction/recharge systems in meeting the goals of the IRA and (2) will allow collection of sufficient data to evaluate whether operational changes may be needed to improve system performance.

The monitoring program described in the plan consists of the following procedures:

- Installation of additional monitoring wells in areas where water-level and/or water-quality information is needed to assess system performance
- Periodic measurement of water levels and collection and analysis of water-quality samples before and after system startup
- Evaluation and reporting of monitoring results to assess system performance and allow operational adjustments

This plan is organized into five sections. The remainder of Section 1.0 describes the purpose, the design and schedule for IRA A, and the objectives of the monitoring program. Section 2.0 describes the existing data used in the design of the monitoring program. Section 3.0 describes the groundwater monitoring well network to be used in the monitoring program. Section 4.0 describes the sampling and analytical program to be employed for the monitoring program. Section 5.0 describes the evaluation and reporting of data collected during the monitoring program.

IRA A is being implemented to remediate contamination to the north of RMA along two primary contaminant pathways, defined by two paleochannels and referred to as the First Creek and Northern pathways. The monitoring program described in this plan was developed by Harding Lawson Associates (HLA) in support of the IRA A remediation program. The purpose of the monitoring program is to allow an assessment of the performance of IRA A so that recommendations can be made for any operational modifications necessary to improve system performance.

1.1 INTERIM RESPONSE ACTION A

This section presents a brief summary of IRA A. Detailed information regarding IRA A design was presented in the Final Implementation Document for IRA A (HLA, 1991a), and the following discussion is summarized from that report.

1.1.1 Purpose of Interim Response Action A

IRA A was designed to ensure localized offpost control of groundwater contaminant migration in a manner similar to the groundwater control systems located along the RMA boundaries. The system was designed on the basis of results of previous RMA monitoring programs, the performance of existing RMA groundwater treatment facilities, and the results of geotechnical and pilot-scale testing conducted in support of IRA A design (HLA, 1990).

IRA A will (1) intercept contaminated alluvial groundwater in each pathway using groundwater extraction wells, (2) remove organic contaminants from the groundwater using granular activated carbon (GAC), and (3) recharge treated water to the alluvial aquifer using recharge wells and trenches. This IRA design is meant to be flexible to enhance the potential for the IRA A design to be compatible with the final remedy (HLA, 1991a).

1.1.2 Design and Components of Interim Response Action A

1.1.2.1 First Creek Pathway

The groundwater extraction and recharge system selected for the First Creek pathway will consist of five extraction wells spaced 200 to 500 feet apart. Four wells will be aligned parallel to the pathway axis, and one well will be located off of the axis. Six recharge trenches will be used to recharge treated water. Four of the recharge trenches will be located along the margins of the pathway and will be oriented parallel to the pathway axis. The two remaining trenches will be aligned perpendicular to the pathway axis and will be located downgradient of the extraction well system. Configuration of the recharge trenches allows a wide geographic distribution of water to enhance flushing of water toward extraction wells and allows treated water to bypass the system to

minimize effects on the downgradient water table. Figure 1.1 shows the general location of wells and trenches and their relationships to the interpreted locations of contaminant plumes.

In several monitoring wells located near O'Brian Canal in the First Creek pathway, concentrations of some organic contaminants exceed IRA remediation goals as defined in the Final Decision Document (HLA, 1989). As a result, some organic contaminant plumes may extend beyond the study area boundary. Therefore, an extraction well array aligned along the pathway axis was selected to allow the most rapid removal of contaminant mass by extracting groundwater from the area of highest contaminant concentration (HLA, 1991a). Although it may not be possible to demonstrate complete hydraulic capture using this array, the system was designed so that the potential for upgradient contaminants bypassing the extraction system will be minimized.

1.1.2.2 Northern Pathway

The groundwater extraction and recharge system selected for the Northern pathway will consist of 12 extraction wells and 24 recharge wells. Extraction wells will be placed approximately 200 feet apart and will be aligned across the paleochannel, perpendicular to the direction of groundwater flow. Recharge wells will be placed approximately 100 feet apart and will be aligned parallel to and approximately 300 feet downgradient of the extraction well alignment. The location and configuration of the system was selected to provide hydraulic capture and to remove contamination above remediation goals within the Northern pathway. Figure 1.1 shows the location of extraction and recharge components relative to contaminant plumes.

1.1.3 Schedule for Implementation

As described in the Implementation Document (HLA, 1991a), IRA A will be implemented in two phases. The first phase will include construction of the treatment facility and Northern pathway extraction and recharge facilities. Startup and operation of these facilities are currently scheduled to begin during the Fall of 1992. The second phase will include construction of First Creek pathway extraction and recharge facilities. During this phase, water produced by construction dewatering in the First Creek pathway will be treated using the treatment facility and will be

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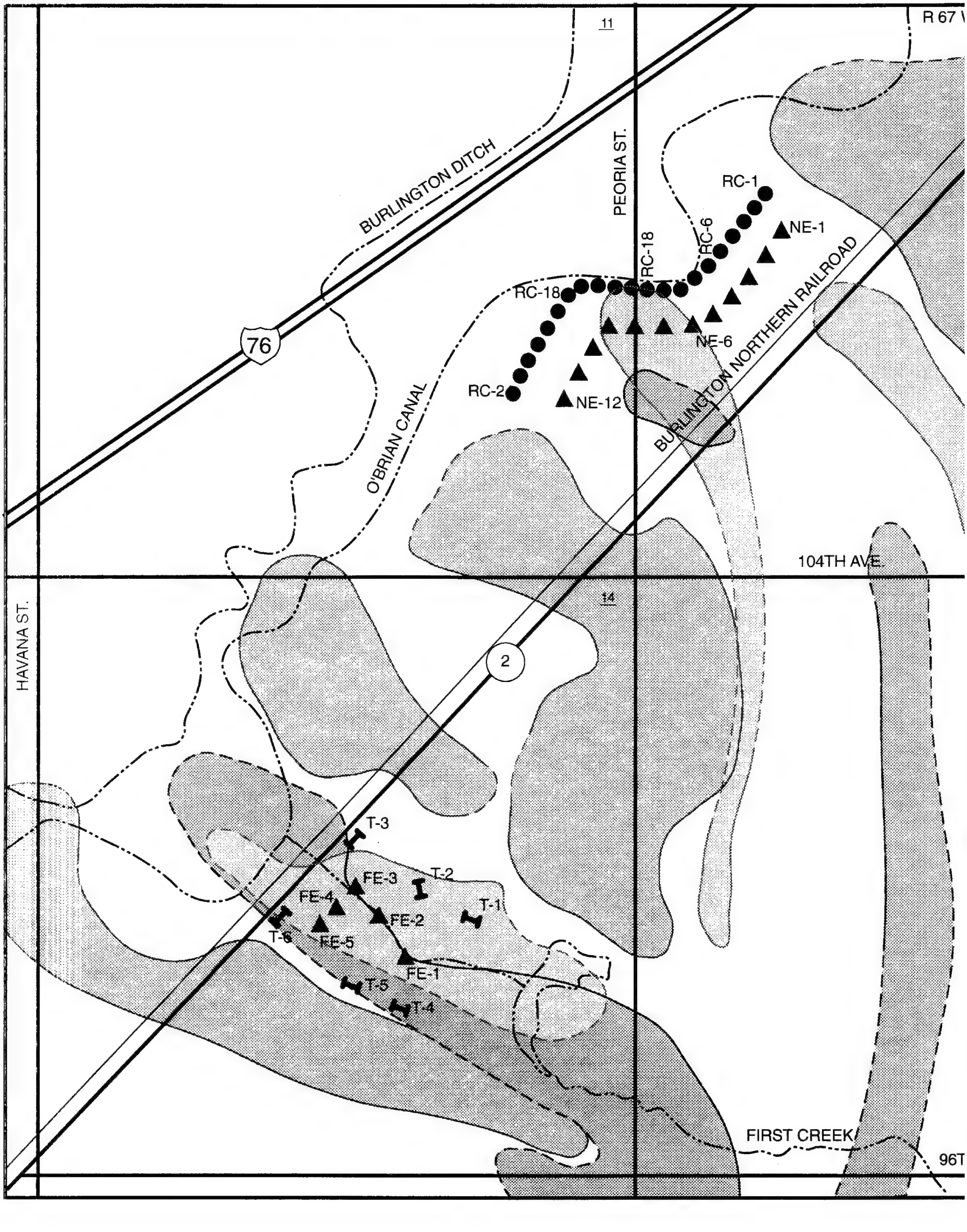
R 67 W
11
BURLINGTON DITCH
PEORIA ST.
RC-1
NE-1
RC-6
RC-18
RC-18
NE-6
BURLINGTON NORTHERN RAILROAD
76
RC-2
NE-12
O'BRIAN CANAL
104TH AVE.
14
HAVANA ST.
2
T-3
T-2
FE-3
FE-4
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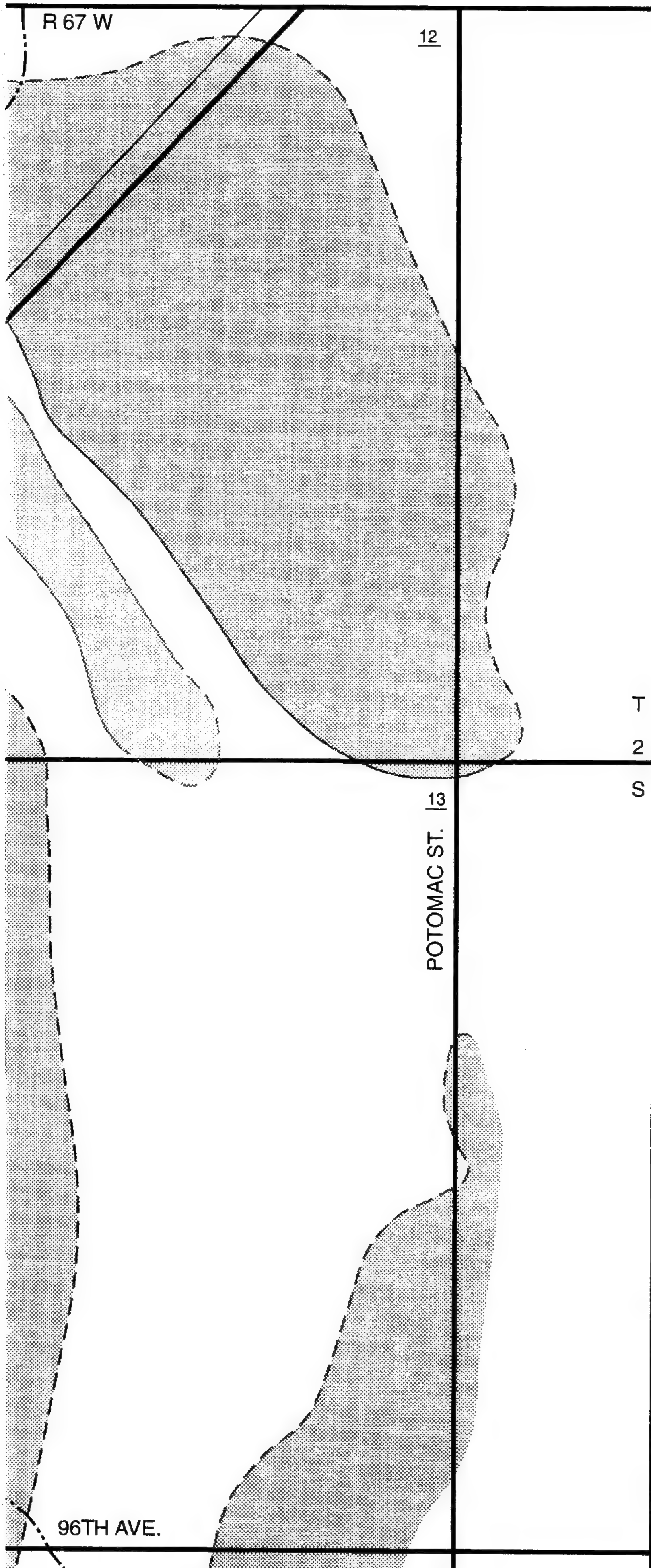

EXPLANATION

Unsaturated alluvium (dashed where inferred)

Areas Where Volatile or Semi-Volatile Compounds Exceed Remediation Goals (Dashed Where Inferred)

Area Where Organochlorine Pesticides Exceed Remediation Goels (Dashed Where Inferred)

Extraction Well

Recharge Well

Recharge Trench

12 Section Number

NOTE: Northern Pathway Wells are Numbered Sequentially from NE-1 through NE-12 and RC-1 through RC-24

N

0 500 1000

Scale in feet

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.1

LOCATIONS OF EXTRACTION/RECHARGE FACILITIES AND CONTAMINANT PLUMES

recharged to the Northern pathway. Startup of the First Creek system and operation of the entire system is currently scheduled to begin during the Spring of 1993.

1.2 MONITORING PROGRAM OBJECTIVES

The objectives of the monitoring program are related to groundwater hydraulics, system operation, and groundwater quality. The following monitoring objectives relate to groundwater hydraulics:

- Assessing whether the Northern pathway system is providing hydraulic capture as designed
- Evaluating the degree of capture provided by the First Creek system
- Assessing hydraulic interactions between the alluvium and the Denver Formation (Fm) in the vicinity of the systems to evaluate the potential beneficial impact of the systems on Denver Fm water quality
- Assessing the effects of First Creek/alluvium interactions and canal leakage on IRA operation
- Evaluating seasonal and long-term changes, if any, to water levels in the vicinity of the systems

The following monitoring objectives relate to system operation:

- Assessing whether flow rates from/to wells or trenches should be changed to improve capture or reduce on/off cycling of the system
- Assessing whether automatic system operation settings (i.e., automatic pump-on or pump-off sensor locations) should be changed to improve overall system efficiency (i.e., pump cycling)
- Assessing whether additional wells/trenches are needed to improve capture and system efficiency

Monitoring objectives related to groundwater quality include the following:

- Assessing contaminant removal efficiency in each pathway
- Assessing impacts of recycling recharged water on water quality
- Assessing when remediation goals have been achieved and system operation can be discontinued

The objectives of the plan will be achieved through installation of additional monitoring wells and collection of water-level and water-quality information from new and existing wells. The monitoring well network and sampling/analytical programs designed to meet these objectives are described in Sections 3.0 and 4.0, respectively.

2.0 DATA USED IN THE DESIGN OF THE MONITORING PROGRAM

The results of previous investigations conducted within the RMA Offpost Operable Unit (OU) and the results of performance assessments of existing RMA extraction/recharge facilities were used in the design of this monitoring program. The following data and assessments were used:

- Geologic, hydrologic, and water-quality data and assessments developed in support of the design of IRA A (HLA, 1990; HLA, 1991a)
- Geologic, hydrologic, and water-quality data and assessments developed in support of the Offpost Remedial Investigation (RI) (Environmental Science and Engineering [ESE] and others, 1988) and RI Addendum (HLA, 1991b)
- Water-quality data and assessments developed as part of ongoing monitoring programs at RMA (R.L. Stollar and Associates [Stollar], 1990)
- Boundary containment/treatment system operational assessment reports (Program Manager for Rocky Mountain Arsenal [PMRMA], 1989; PMRMA, 1988; Program Manager Staff Office [PMSO]-PMRMA, 1987)

Detailed geologic, hydrologic, and water-quality information was collected in support of IRA A design, is described in detail in the Pilot-Scale Testing Results Report (HLA, 1990), and is summarized below.

During the IRA A geotechnical investigation, 47 soil borings were drilled, and monitoring wells were installed in 7 of these borings. An additional 24 borings were drilled for pilot-scale testing. Test wells were installed in 6 borings, piezometers were installed in 14 borings, and 4 borings were plugged and abandoned.

Borings drilled during the geotechnical investigation were located in areas where additional geologic information was needed for IRA A design, with the greatest concentration of borings in areas considered to be the most likely sites for pilot-scale hydraulic system components and along expected paleochannel axes and margins. Geologic information obtained from new and existing borings and wells was used to prepare a revised bedrock contour map to delineate paleochannel locations more accurately, to refine previous interpretations of the potentiometric surface, and to assess the saturated alluvial thickness within the study area.

Analytical results for groundwater samples collected from the seven monitoring wells and six pilot-test wells were combined with Comprehensive Monitoring Program (CMP) data (Spring 1989) and were used to prepare detailed chemical plume maps for the three primary constituents (chloroform, dieldrin, and diisopropylmethyl phosphonate [DIMP]) affecting system location (HLA, 1990).

3.0 DESIGN OF THE GROUNDWATER MONITORING WELL NETWORK

This section describes the monitoring well network selected to assess the performance of the IRA A extraction/recharge systems. The monitoring network includes the following wells:

- Existing alluvial monitoring wells and new alluvial monitoring wells to be installed specifically for IRA A monitoring
- Existing Denver Fm monitoring wells and new Denver Fm monitoring wells to be installed specifically for IRA A monitoring

Locations for monitoring wells were selected on the basis of the monitoring program objectives, as described in Section 1.2, and on the basis of the locations of existing monitoring wells. Specific criteria used to establish locations for new monitoring wells are described in Section 3.1. Sections 3.2 and 3.3 describe the locations for additional monitoring wells selected within the First Creek and Northern pathways, respectively, on the basis of objectives discussed in Section 1.2 and the criteria described in Section 3.1. Section 3.4 discusses the possible need for additional monitoring well locations not described in this monitoring plan.

3.1 CRITERIA FOR SELECTING ADDITIONAL MONITORING LOCATIONS

A network of new and existing monitoring wells will be established to meet the IRA A monitoring objectives described in Section 1.2. Locations for new monitoring wells were selected on the basis of following criteria:

- New monitoring wells will be located only in areas where either (1) there are no existing monitoring wells or (2) the number and/or locations of existing wells are not sufficient to meet monitoring objectives. Existing wells will be used to the maximum extent practicable.
- New wells will be located so that they, together with existing monitoring wells, will allow collection of water-level data that can be used to assess the degree of hydraulic capture provided by each extraction/recharge system.
- Wells will be located to provide a means to assess the impact of First Creek on system operation.
- Wells will be located downgradient of extraction/recharge systems to provide a means of assessing the impact of the systems on local groundwater flow patterns and assessing the impact of IRA A system groundwater recharge versus canal leakage on downgradient water quality.

- Monitoring wells will be located upgradient of the extraction/recharge system to provide a means to assess the migration of contaminants toward the system and to assess when the system operation achieves its objective of alluvial groundwater remediation and may therefore be discontinued.

- Monitoring wells will be located to provide an indication of the possible beneficial impacts of extraction/recharge operations on water quality in the Denver Fm.

Sections 3.2 and 3.3 describe new monitoring locations selected for the First Creek and Northern pathways, respectively, on the basis of specific criteria described above. The sampling and analytical program to be conducted using the monitoring well network is described in Section 4.0.

3.2 FIRST CREEK PATHWAY

The locations of existing monitoring wells and monitoring wells to be installed for the IRA A monitoring program, within the First Creek pathway, are shown on Plate 1. Tables 3.1 and 3.2 list each new alluvial and Denver Fm well to be installed within the First Creek pathway and the rationale for its installation.

As described in Section 1.1.2, the First Creek pathway extraction/recharge system was designed to allow the most rapid removal of contaminant mass by extracting groundwater from the area of highest contaminant concentration, the pathway axis. The alluvial monitoring well network within the First Creek pathway has been designed to allow a detailed assessment of the alluvial potentiometric surface in the vicinity of the extraction/recharge system. This assessment of the alluvial potentiometric surface will facilitate an evaluation of the influence of the system on groundwater flow and the degree of capture provided by the system. The alluvial monitoring network was also designed to assess water chemistry in the vicinity of the system and to evaluate the effectiveness of contaminant removal.

As shown in Table 3.1, alluvial monitoring wells A-36 through A-39 will be located downgradient of the First Creek extraction/recharge system. These new wells will supplement the existing alluvial network and provide information on downgradient water quality and the effect of the system on downgradient water levels.

Table 3.1: Additional Alluvial Monitoring Wells to be Installed within the First Creek Pathway

Well No.	Siting Rationale
A-36 and A-37	Monitor water quality and water levels downgradient of the system and O'Brian Canal to assess the impact of the canals versus the IRA A system on contaminant plumes.
A-38 and A-39	Monitor water quality and water levels to supplement the existing alluvial monitoring network in the area downgradient of the system and upgradient of O'Brian Canal.
A-40 through A-53	Monitor water quality and water levels within the system to assess the degree of hydraulic capture provided by the system and the effect of the system on alluvial water quality. Wells A-43 and A-46 will provide additional water-quality and water-level data in the vicinity of First Creek to aid in assessing the relationship between First Creek and IRA A remediation activities. Wells A-40, A-47, A-49, and A-53 will also be used, together with piezometers located within recharge trenches, to assess trench performance and potential clogging.
A-54 and A-55	Monitor water quality and water levels in the vicinity of recharge trench T-1 to assess the impact of system operation on water quality within the arm of the paleochannel that extends north from the First Creek pathway.
A-56 and A-57	Monitor water quality and water levels upgradient of the system to assess changes in alluvial water levels and quality over time. These wells will also be used to assess changes in the tail end of the contaminant plumes in the pathway.

IRA A = Interim Response Action A

Table 3.2: Additional Denver Formation Monitoring Wells to be Installed within the First Creek Pathway

Well No.	Siting Rationale
D-13	Supplement existing Denver Fm monitoring network downgradient of the system to assess the potential beneficial effect of the system on the Denver Fm water quality. Evaluate changes in Denver Fm water levels as a function of IRA A operation.
D-14 through D-17	Monitor water quality and water levels in the vicinity of the system to assess the impact of remediation activities on the Denver Fm water quality. Wells D-15 and D-16 will also be used to assess the impact of increased alluvial water levels (associated with trenches T-5 and T-2, respectively) on Denver Fm water levels and water quality.
D-18	Monitor water quality and water levels upgradient of the system to aid in the assessment of the Denver Fm water quality outside of the influence of the system.

Denver Fm = Denver Formation
IRA A = Interim Response Action A

Alluvial monitoring wells A-40 through A-53 will be located within the extraction/recharge system. The primary purpose of these wells will be to provide water-level information to assess the degree of capture provided by the system and to evaluate the need for operational changes to improve system efficiency.

As stated in Table 3.1, alluvial monitoring wells A-54 and A-55 will be located in the vicinity of recharge trench T-1 and will be used to assess the impact of recharge activities on groundwater quality and flow within the arm of the paleochannel that extends north from the First Creek pathway. This pathway has a saturated alluvial thickness of less than 5 feet and may only be active when alluvial water levels are high (HLA, 1990). The recharge of treated water into the alluvial aquifer using recharge trench T-1 is expected to inhibit the migration of contaminants through the marginal pathway (HLA, 1991a). The monitoring will thus be conducted to demonstrate that contaminants are not exiting the First Creek pathway at this location.

Alluvial monitoring wells A-56 and A-57 will be installed upgradient of the extraction/recharge system and will supplement the existing network of monitoring wells upgradient of the system. These wells will be used to monitor water quality upgradient of the system to assess the migration of the plumes and evaluate when system operation can be discontinued. Additionally, water-level data from these wells will be used to assess seasonal and long-term variations in alluvial water levels upgradient of the system.

A network of Denver Fm monitoring wells (Table 3.2) will also be installed in addition to the alluvial monitoring network. Denver Fm wells will be paired with alluvial wells to evaluate vertical hydraulic gradients between the alluvium and the Denver Fm and to assess the potential impact of system operation on Denver Fm water levels and quality.

As shown in Table 3.2, Denver Fm monitoring well D-13 will be installed downgradient of the First Creek extraction/recharge system to supplement the existing Denver Fm well network in this area. Information from this well will be used to assess the potential impact of system operation on Denver Fm water quality downgradient of the system.

Denver Fm monitoring wells D-12 through D-17 will be installed in the vicinity of the extraction/recharge system. The primary function of these wells will be to measure water levels in the Denver Fm to assess changes in the vertical hydraulic gradient that are a result of system operation.

Denver Fm monitoring well D-18 will be installed upgradient of the extraction/recharge system. This well will supplement the existing Denver Fm network in this area and will provide water-quality and water-level information.

3.3 NORTHERN PATHWAY

The locations of existing monitoring wells and monitoring wells to be installed for this monitoring program, within the Northern pathway, are shown on Plate 1. Tables 3.3 and 3.4 list each new alluvial and Denver Fm well to be installed in the Northern pathway with the rationale for its installation.

As described in Section 1.1.2, the Northern pathway extraction/recharge system was designed to remediate groundwater contamination by providing hydraulic capture of contamination above remediation goals.

The primary objective of the alluvial monitoring system is to provide hydraulic data that can be used to demonstrate hydraulic capture in the alluvial aquifer in the area between the extraction and recharge wells. In addition, water-quality information will be collected upgradient, downgradient, and in the vicinity of the system to allow an assessment of the effects of system operations on the distribution and migration of contaminants.

The system of monitoring wells proposed for the Northern pathway will allow evaluation of hydraulic gradients between extraction and recharge well lines. Monitoring will be performed in the alluvial aquifer system between each extraction well, and downgradient of the extraction well line, to assess whether hydraulic capture was achieved. In addition, hydraulic gradients in the uppermost Denver aquifer zone will be assessed at selected locations in the vicinity of the system. This assessment will provide information regarding potential gradient reversals in the Denver Fm as a result of alluvial aquifer groundwater extraction and recharge. Denver Fm wells will be

paired with alluvial wells to allow evaluation of vertical hydraulic gradients. The locations of all wells are shown on Plate 1, and explanations of the specific rationale for siting each well are provided in Tables 3.3 and 3.4.

As shown in Table 3.3, alluvial monitoring wells A-1 through A-6 will be installed downgradient of the Northern pathway extraction/recharge system. These wells will supplement the existing downgradient alluvial monitoring network and will provide water-level and water-quality information to assess the impact of system operation on downgradient alluvial ground-water. In addition, wells A-2 and A-6 will provide water-quality information to monitor contaminants that may bypass the system along the margins of the pathway.

Alluvial monitoring wells A-7 through A-32 will be installed within the extraction/recharge system. The primary function of these wells will be to provide water-level information to assess the degree of hydraulic capture provided by the system and to evaluate the need for operations adjustments to improve system efficiency. In addition to water-level data, wells A-20 through A-32 will provide information regarding the concentration and distribution of contaminants approaching the system.

Alluvial wells A-33 through A-35 will be installed upgradient of the extraction/recharge system and will supplement the existing alluvial network in this area. These wells will provide information regarding alluvial water quality upgradient of the system and will be used to assess seasonal or long-term water-level changes within the pathway.

The alluvial monitoring network will also be used to provide site-specific geologic information in the vicinity of the Northern pathway system. Specifically, during installation of alluvial monitoring wells, geologic data will be collected to confirm expected geologic conditions along the system alignment. In some areas along the alignment, geologic conditions were estimated on the basis of geophysical data and other geologic information within the Northern pathway. Collecting site-specific data near each extraction and recharge well will be of significant benefit in confirming geologic conditions that were assumed in designing the extraction and recharge wells.

Table 3.3: Additional Alluvial Monitoring Wells to be Installed within the Northern Pathway

Well No.	Siting Rationale
A-1 and A-4	Monitor water quality and water levels downgradient of the system and O'Brian Canal.
A-2	Monitor water quality and water levels to assess if contaminants may bypass the system along the northeastern margin of the pathway.
A-3 and A-5	Monitor water quality and water levels downgradient of the system and upgradient of O'Brian Canal.
A-6	Monitor water quality and water levels to assess if contaminants may bypass the system along the southwestern margin of the pathway.
A-7 through A-19	Monitor water levels between extraction and recharge wells to aid in assessing hydraulic capture.
A-20 through A-32	Monitor water levels and water quality between extraction wells to assess water quality approaching the system and to aid in assessing hydraulic capture.
A-33 and A-34	Monitor water levels and water quality to supplement existing upgradient monitoring network and aid in the assessment or contaminants approaching the system.
A-35	Monitor water levels and water quality to supplement existing upgradient monitoring network and aid in the assessment of changes in the concentrations of contaminants upgradient of the system over time.

Table 3.4: Additional Denver Formation Monitoring Wells to be Installed within the Northern Pathway

Well No.	Siting Rationale
D-1	Monitor water quality and water levels downgradient of the system and upgradient of O'Brian Canal to assess the effect of system operation on the Denver Fm.
D-2	Monitor water quality and water levels downgradient of the system and O'Brian Canal to assess the effect of system operation on the Denver Fm.
D-3	Monitor water quality and water levels downgradient of the system and upgradient of O'Brian Canal to assess the effect of system operation on the Denver Fm.
D-4 through D-9	Monitor water quality and water levels within the extraction/recharge system to assess the probable effect of system operation on the Denver Fm.
D-10	Monitor water quality and water levels upgradient of the system to assess the possible effect of alluvial contamination on the Denver Fm.
D-11	Monitor water quality and water levels upgradient of the system to assess the possible effect of alluvial contamination on the Denver Fm.
D-12	Monitor water quality and water levels upgradient of the system to assess the possible effect of alluvial contamination on the Denver Fm.

Denver Fm = Denver Formation

As previously stated, Denver Fm monitoring wells will be installed to assess the potential effect of system operations on Denver Fm water quality. Each Denver Fm well will be paired with an alluvial well to allow an assessment of vertical hydraulic gradients. Denver Fm wells located in the immediate vicinity of the extraction/recharge system will be used to assess the potential beneficial impact of system operations on the Denver Fm. Additional Denver Fm wells will be used to assess water quality in the Denver Fm both upgradient and downgradient of the system.

As Table 3.4 shows, Denver Fm monitoring wells D-1 through D-3 will be installed downgradient of the groundwater extraction and recharge system and will provide information regarding Denver Fm water quality in this area. Denver Fm monitoring wells D-4 through D-9 will be installed along the extraction/recharge system alignment. The primary function of these wells will be to assess the effect of system operation on the potentiometric surface of the Denver Fm.

Denver Fm monitoring wells D-10 through D-12 will be installed upgradient of the extraction/recharge system. These wells will be used to augment the existing Denver Fm monitoring well network to provide data to assess Denver Fm water quality and monitor seasonal or long-term changes in the Denver Fm potentiometric surface.

3.4 ADDITIONAL MONITORING WELLS

In conjunction with the 75 monitoring wells proposed in this monitoring plan, provisions for installation of up to 35 additional monitoring wells have been made by PMRMA. These wells will be installed as needed to (1) provide more detailed monitoring of system performance in areas where operational monitoring indicates additional detail is required to more fully assess IRA system's impacts on the local hydrogeologic system (it is likely that the need for such wells will become apparent in the first few months after system start-up and the preliminary monitoring data have been evaluated), (2) assess the long-term hydraulic performance of recharge trenches, and (3) replace any monitoring wells that may be damaged or destroyed during IRA A construction activities.

The additional monitoring wells may be constructed, depending on the need, in both the Denver and alluvial aquifers. The monitoring wells may be located upgradient or downgradient of the systems. It is anticipated that the majority of the monitoring wells will be located within the immediate area of the extraction and recharge systems. Specific locations for the potential additional monitoring wells cannot be selected until the need for individual wells is identified. Therefore, none of the locations of the 35 wells has been shown in this monitoring plan.

4.0 SAMPLING AND ANALYTICAL PROGRAM

This section describes the sampling and analytical program to be conducted using the monitoring well network described in Section 3.0 The sampling and analytical program is designed to provide the water-quality and water-level data required to support an assessment of the performance of the IRA A extraction/recharge systems, and to provide data needed to indicate what operational changes, if any, may be needed to optimize system performance.

The sampling and analytical program will be conducted in two phases:

1. A baseline monitoring phase designed to permit a detailed assessment of water-quality and groundwater flow before system startup
2. An operational monitoring phase designed to support an assessment of the performance of the system over time and to allow recommendations for operational modifications that may be necessary to improve system performance

As described in Section 3.0, the monitoring network will consist of both existing wells and new wells that will be installed specifically for this monitoring program. The locations of wells to be sampled and measured for water levels, and the locations of wells to be measured for water levels only are shown on Plate 2.

4.1 BASELINE MONITORING

Baseline monitoring will be conducted before IRA A startup and will consist of water-level and water-quality monitoring. The purpose of baseline monitoring will be to assess conditions before IRA A system operation, thus providing a benchmark with which the results of operational monitoring can be compared. Baseline monitoring will be conducted once each quarter until system startup.

4.1.1 Water-level Monitoring

To understand the effect the extraction/recharge system has on the local potentiometric surface, baseline data are necessary. Plate 2 shows the wells to be included in baseline water-level monitoring. The network of wells to be measured for water levels includes all new and existing monitoring wells located within the First Creek and Northern pathways. Water-level

measurements will also be taken during baseline monitoring from any installed extraction wells, recharge wells, and recharge trench piezometers (three per trench) to help understand the potentiometric surface before system startup. Approximately 165 alluvial wells and 35 Denver Fm wells will be included.

Water-level measurements will be coordinated to collect data in the shortest possible time span, preferably within one day per pathway. The short time span will allow the construction of time-equivalent potentiometric maps.

4.1.2 Water-quality Monitoring

The monitoring wells to be sampled for water quality are shown on Plate 2. The purpose of this sampling is to provide a basis for the evaluation of the long-term effectiveness of the system by comparing nearby water quality before system operation with data collected during operational monitoring.

4.2 OPERATIONAL MONITORING

Operational monitoring will provide quarterly water-quality and water-level data to allow an assessment of the performance of IRA A. Water levels will be monitored and water-quality samples will be collected on a quarterly basis.

4.2.1 Water-level Monitoring

Following system startup, water-levels will be measured once each quarter for one year using the same network of wells as during baseline monitoring. In addition, water-levels will be measured in all extraction and recharge wells and in piezometers installed in recharge trenches. Water-level data from operational monitoring will be compared with baseline monitoring data to assess the effect of system operation on the alluvial water table and the degree of hydraulic capture provided by the systems.

It is anticipated that more frequent water-level measurements will be required during system start-up and when changes are made to extraction or recharge rates.

Water-level measurements will be coordinated to collect data in the shortest possible time span, preferably within one day per pathway. This collection will be done to obtain a set of measurements for each sampling period such that the resulting potentiometric maps will be temporally comparable.

4.2.2 Water-quality Monitoring

During operational monitoring, water-quality samples will be collected from the same wells that will be sampled during baseline monitoring. Water-quality sampling will initially be conducted quarterly, but the frequency of monitoring may be reduced if initial results show that the concentration and distribution of contaminants can be adequately monitored using less frequent sampling.

4.3 ANALYTICAL PROGRAM

Water-quality samples collected during baseline and operational monitoring will be analyzed for the constituents shown in Table 4.1. The analytes shown in Table 4.1 were selected on the basis of the results of previous monitoring programs conducted at RMA. The target analyte list has been continually updated by evaluating gas chromatography/mass spectrometry (GC/MS) screening data obtained from regional monitoring programs and incorporating those contaminants that may require eventual remediation. Field parameters, including pH, temperature, and specific conductance, will be measured to ensure representative water samples and to assess the potential communication between aquifers. Laboratory water-quality analyses will be conducted using PMRMA-certified procedures designed to ensure accurate and precise determination of the analytes considered.

During operational monitoring, the benefit of using a reduced analytical schedule for frequent (i.e., quarterly) monitoring versus using the full analyte suite for less frequent (i.e., annual) monitoring will be assessed.

Table 4.1: Target Analytes for the Interim Response Action A Monitoring Program
(Page 1 of 2)

ANALYSIS/METHODS/ANALYTES

AGENT PRODUCTS/HPLC

Thiodiglycol

AGENT PRODUCTS/IONCHROM

Isopropylmethylphosphonic acid

METALS/ICP

Cadmium
Chromium
Copper
Lead
Zinc

ORGANOPHOSPHORUS COMPOUNDS/GC/FPD

Diisopropylmethyl phosphonate (DIMP)
Dimethylmethyl phosphonate (DMMP)

SEMIVOLATILE ORGANIC COMPOUNDS/GC/MS

1,4-Oxathiane
2,2-bis(Para-chlorophenyl)-1,1-dichloroethane
2,2-bis(Para-chlorophenyl)-1,1,1-trichloroethane
Aldrin
Atrazine
Chlordane
Chlorophenylmethyl sulfide
Chlorophenylmethyl sulfone
Chlorophenylmethyl sulfoxide
Dibromochloropropane (DBCP)
Dicyclopentadiene (DCPD)
Dieldrin
Diisopropylmethyl phosphonate (DIMP)
Dimethylmethyl phosphonate
Dithiane
Endrin
Hexachlorocyclopentadiene (HCCPD)
Isodrin
Malathion
Parathion
Supona
Vapona

ORGANOCHLORINE PESTICIDES/GC/ECD

2,2-bis(Para-chlorophenyl)-1,1-dichloroethane
2,2-bis(Para-chlorophenyl)-1,1,1-trichloroethene
Aldrin
Chlordane
Dieldrin
Endrin
Hexachlorocyclopentadiene
Isodrin

NITROSAMINES/GC/NPD

N-nitrosodimethylamine

ORGANOPHOSPHORUS PESTICIDES/GC/NPD

Atrazine
Malathion
Parathion
Supona
Vapona

ORGANOSULPHUR COMPOUNDS/GC/NPD

1,4-Oxathiane
Chlorophenylmethyl sulfide
Chlorophenylmethyl sulfone
Chlorophenylmethyl sulfoxide
Dimethyldisulfide
Dithiane

VOLATILE AROMATIC ORGANIC COMPOUNDS/GC/PID

Benzene
Ethylbenzene
m-Xylene
o- and p-Xylene
Toluene

VOLATILE HALOGENATED ORGANIC COMPOUNDS/GC/PID

1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Carbon tetrachloride

Table 4.1: (Page 2 of 2)

VOLATILE HALOGENATED
ORGANIC COMPOUNDS/GC/PID (continued)

- Chlorobenzene
- Chloroform
- Methylene chloride
- Tetrachloroethylene
- trans-1,2-Dichloroethylene
- Trichloroethylene

VOLATILE HYDROCARBON
COMPOUNDS/GCFID

- Bicycloheptadiene
- Dicyclopentadiene
- Methylisobutyl ketone (MIBK)

ARSENIC/AA

DIBROMOCHLOROPROPANE/GC/ECD

MERCURY/AA

CYANIDE/TECHNICON

ANIONS/IONCHROM

- Chloride
- Fluoride
- Sulfate

CATIONS/ICP

- Calcium
- Magnesium
- Sodium
- Potassium

VOLATILE ORGANIC
COMPOUNDS/GC/MS

- 1,1-Dichloroethane
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- Benzene
- Bicycloheptadiene (BCHPD)
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Dibromochloropropane (DBCP)
- Dicyclopentadiene
- Dimethyldisulfide
- Ethylbenzene
- m-Xylene
- Methylene chloride
- Methylisobutyl ketone (MIBK)
- o- and p-Xylene
- Tetrachloroethylene
- Toluene
- trans-1,2-Dichloroethylene
- Trichloroethylene

ALKALINITY

CONDUCTIVITY

pH

NITRATE/NITRITE/COLORIMETRIC

Analytic Methods of Analyses

AA = Atomic Absorption Spectroscopy
GC/CON = Gas Chromatography/Conductivity Detector
GC/ECD = Gas Chromatography/Electron Capture Detector
GC/FID = Gas Chromatography/Flame Ionization Detector
GC/FPD = Gas Chromatography/Flame Photometric Detector
GC/MS = Gas Chromatography/Mass Spectrometry
GC/NPD = Gas Chromatography/Nitrogen Phosphorous Detector
GC/PID = Gas Chromatography/Photoionization Detector
HPLC = High Performance Liquid Chromatography
ICP = Inductively Coupled Argon Plasma Screen
IONCHROM = Ion Chromatography
TECHNICON = Automated Spectrophotometer

5.0 EVALUATION AND REPORTING OF RESULTS

As discussed previously, the results of the IRA A monitoring program will be used to assess the performance of the system and to evaluate whether operational changes are needed to maximize system performance. In addition, because monitoring wells to be installed for the monitoring program will likely be installed before extraction and recharge systems, additional geologic data will be used to assess whether any modifications to well design for IRA A (i.e., screen length, completion intervals) are needed.

The results of baseline and operational monitoring will be evaluated and reported as follows:

- Geologic, geophysical, analytical, and water-level data will be reported to PMRMA as soon as these data have been reviewed and are in final form.
- Interpretations on the basis of field and analytical data will be presented in periodic reports presenting assessments of the performance of IRA A.

Performance assessment reports for IRA A will be prepared approximately annually and will include assessments of the performance of the extraction/recharge systems in meeting the IRA objectives. In addition to annual reports, it would be beneficial to prepare brief quarterly reports during the first six months of operation, the period during which most operational changes will be recommended.

Geologic information obtained from boring and geophysical logs generated during drilling of the monitoring well locations will be incorporated into the existing database. These data can be used in preparing revised maps, as appropriate.

Results of the water-quality analyses should be used to assess changes in contaminant distribution for selected target analytes. This information will be used to evaluate system performance relative to IRA objectives.

Water-level data should be used to develop potentiometric maps of the Offpost OU and cross sections of water levels across the system, parallel to the direction of groundwater flow. These data will be used to assess the degree of hydraulic capture provided by the system and to evaluate whether operational changes are needed.

The reports will provide a means to document changes over time as a result of IRA A operation and will be prepared for distribution to the Organizations and State.

6.0 ACRONYMS AND ABBREVIATIONS

AA	atomic absorption spectroscopy
Army	U.S. Department of the Army
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMP	Comprehensive Monitoring Program
DIMP	diisopropylmethyl phosphonate
ESE	Environmental Science and Engineering
Fm	Formation
GAC	granular activated carbon
GC/ECD	gas chromatography/electron capture detector
GC/FID	gas chromatography/flame ionization detector
GC/FPD	gas chromatography/flame photometric detector
GC/MS	gas chromatography/mass spectrometry
GC/NPD	gas chromatography/nitrogen phosphorus detector
GC/PID	gas chromatography/photoionization detector
HLA	Harding Lawson Associates
HPLC	high performance liquid chromatography
ICP	inductively coupled argon plasma screen
IRA	Interim Response Action
IONCHROM	ion chromatography
NPL	National Priorities List
OU	operable unit
PMRMA	Program Manager for Rocky Mountain Arsenal
PMSO	Program Manager Staff Office
RAO	Remedial Action Objectives
RI	remedial investigation

RMA	Rocky Mountain Arsenal
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
TECHNICON	automated spectrophotometer
USATHAMA	U.S. Army Toxic and Hazardous Material Agency

7.0 REFERENCES

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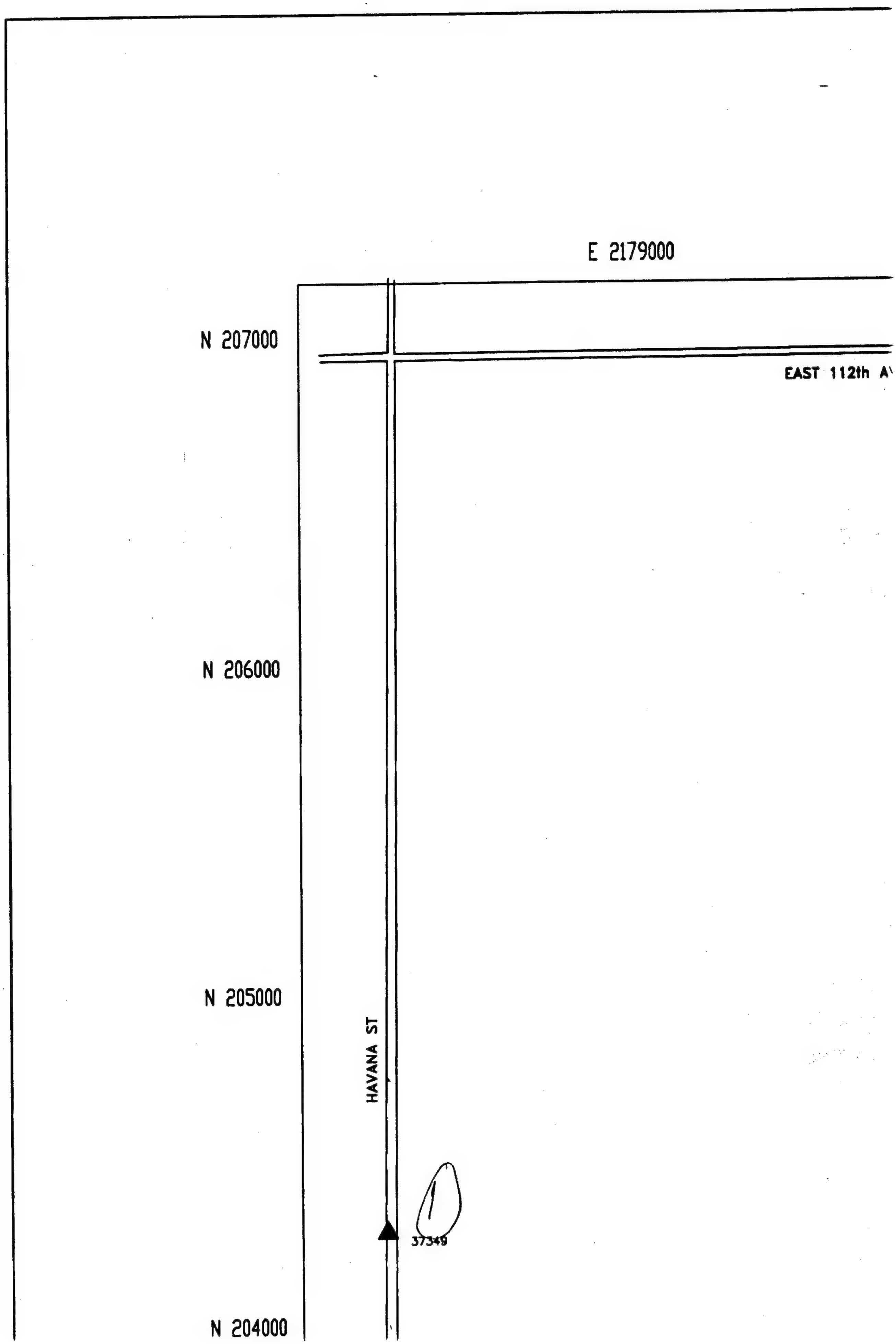
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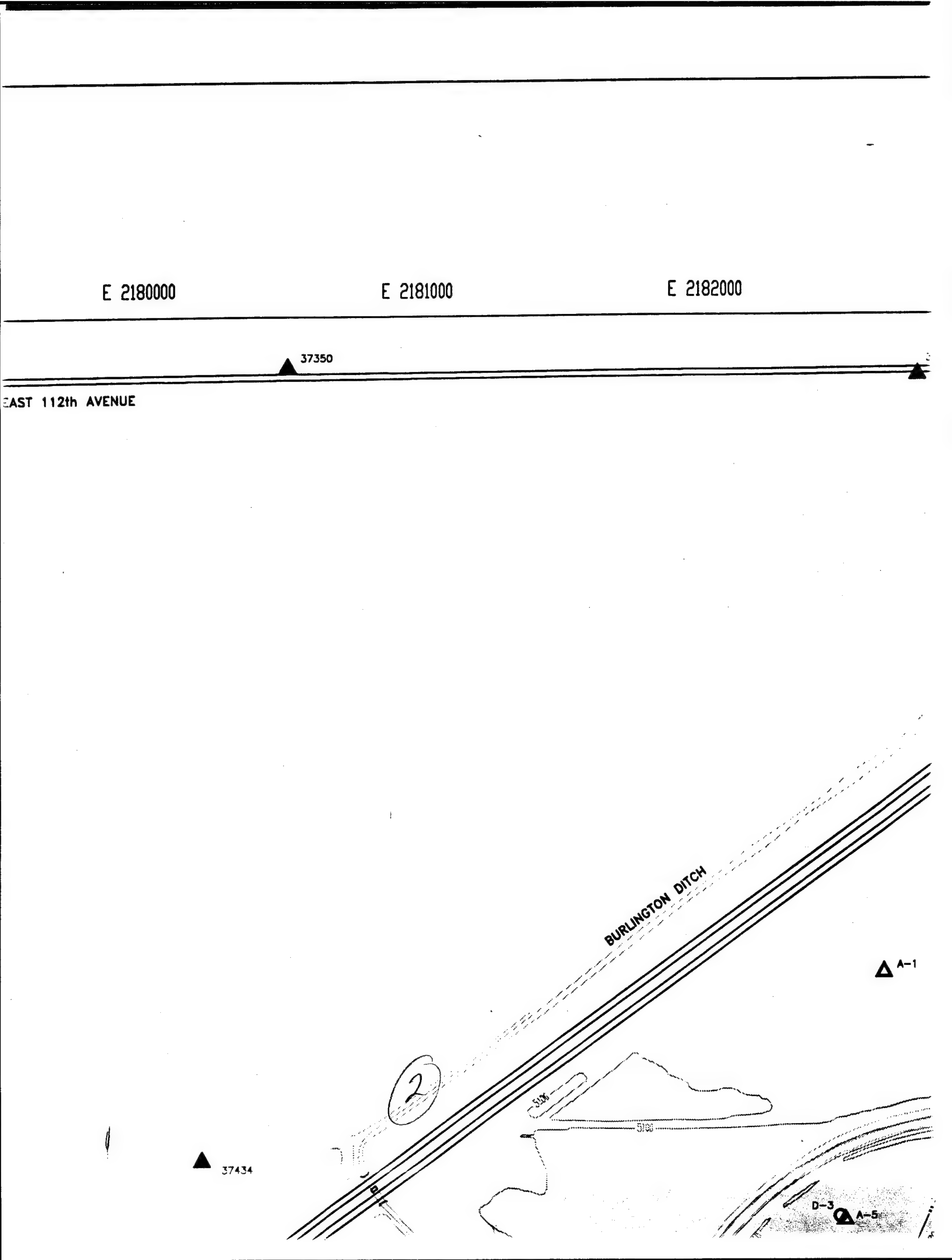
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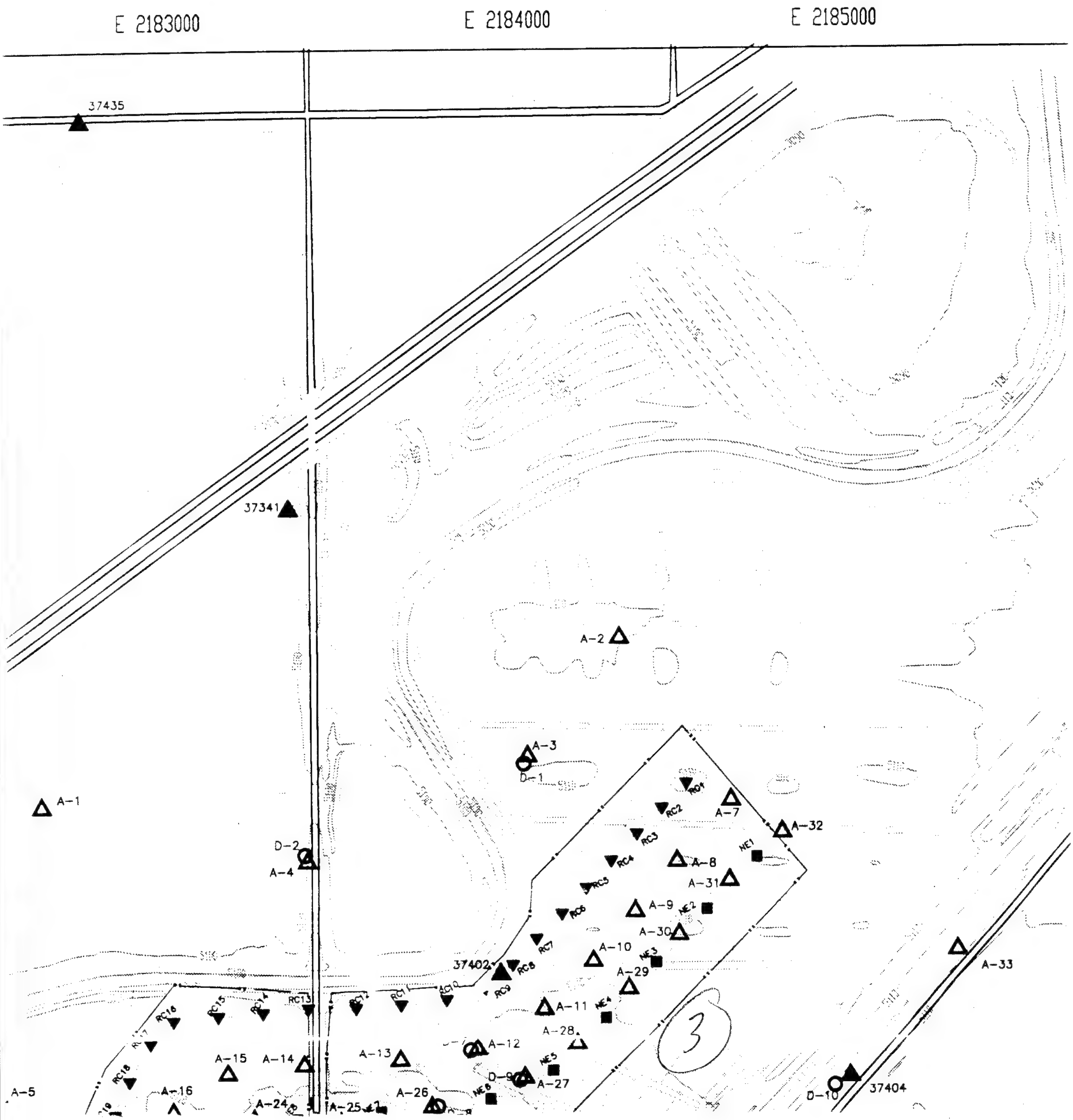

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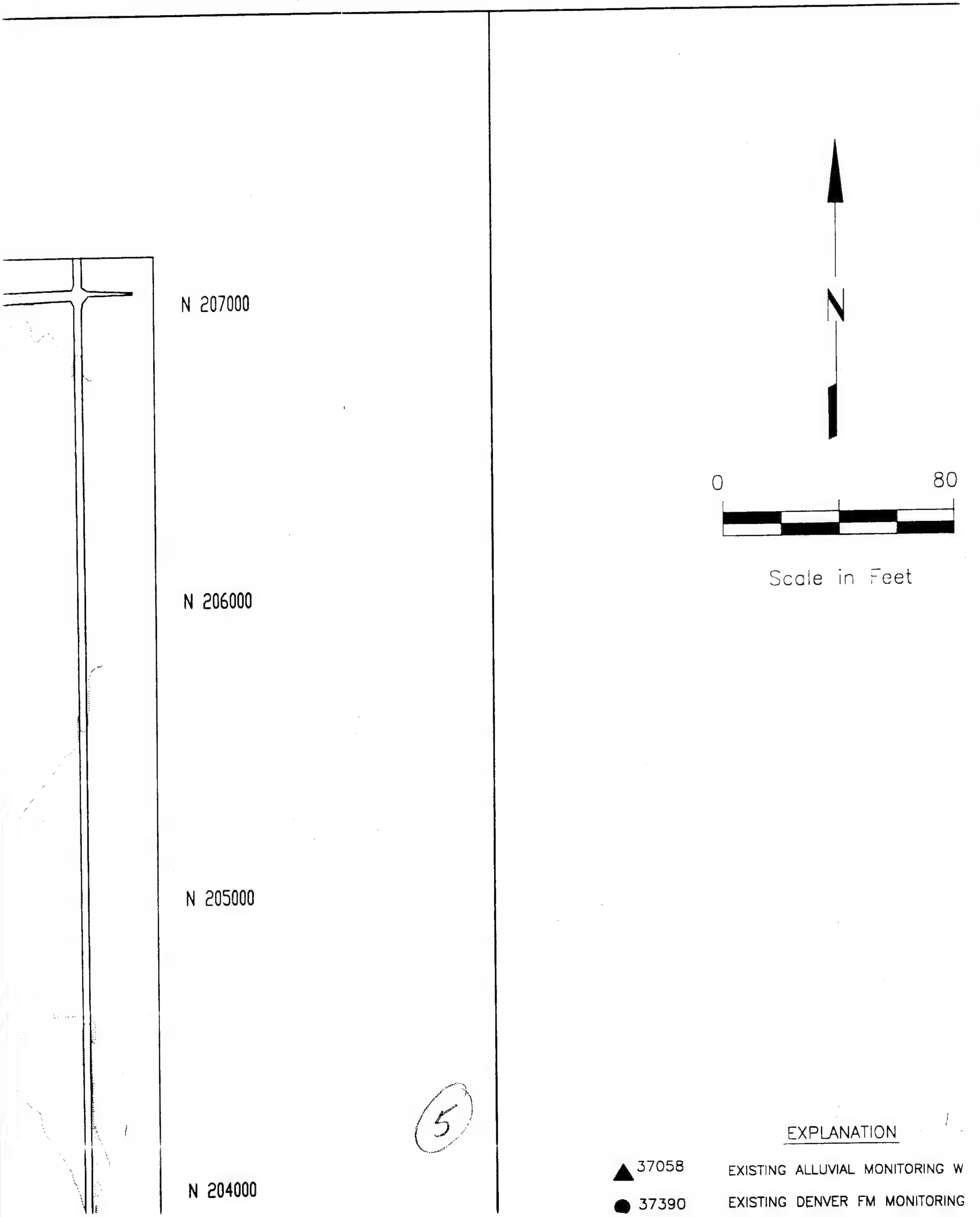
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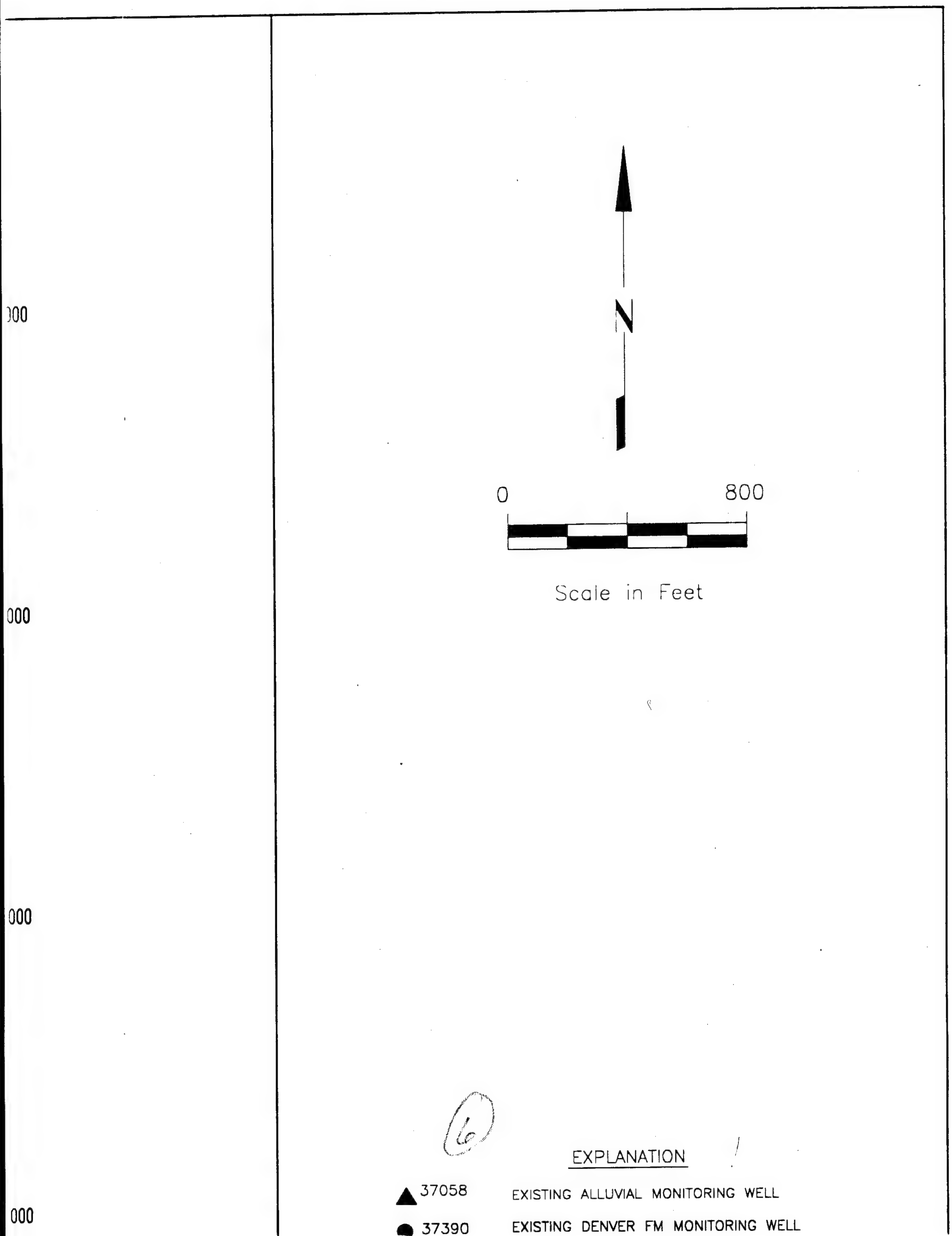

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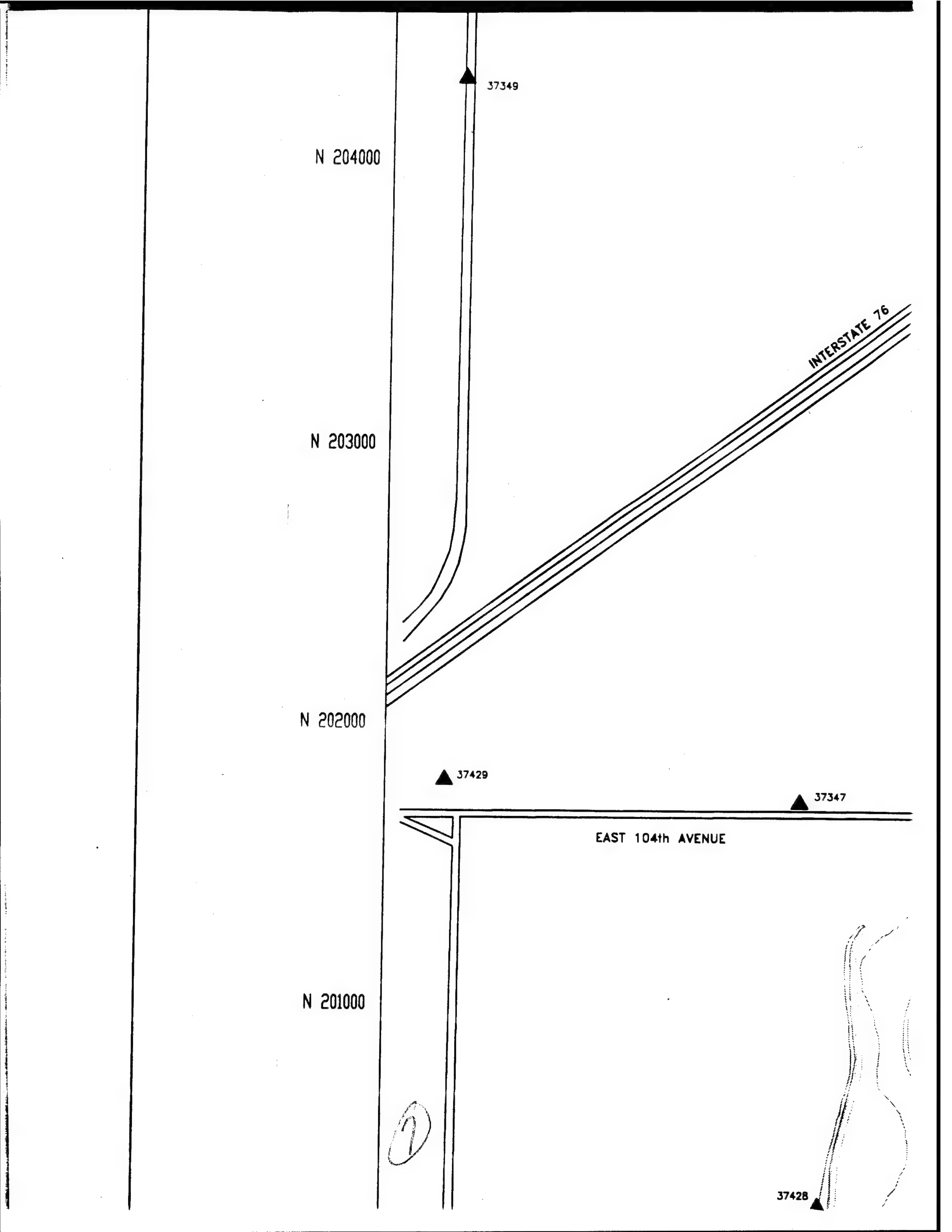
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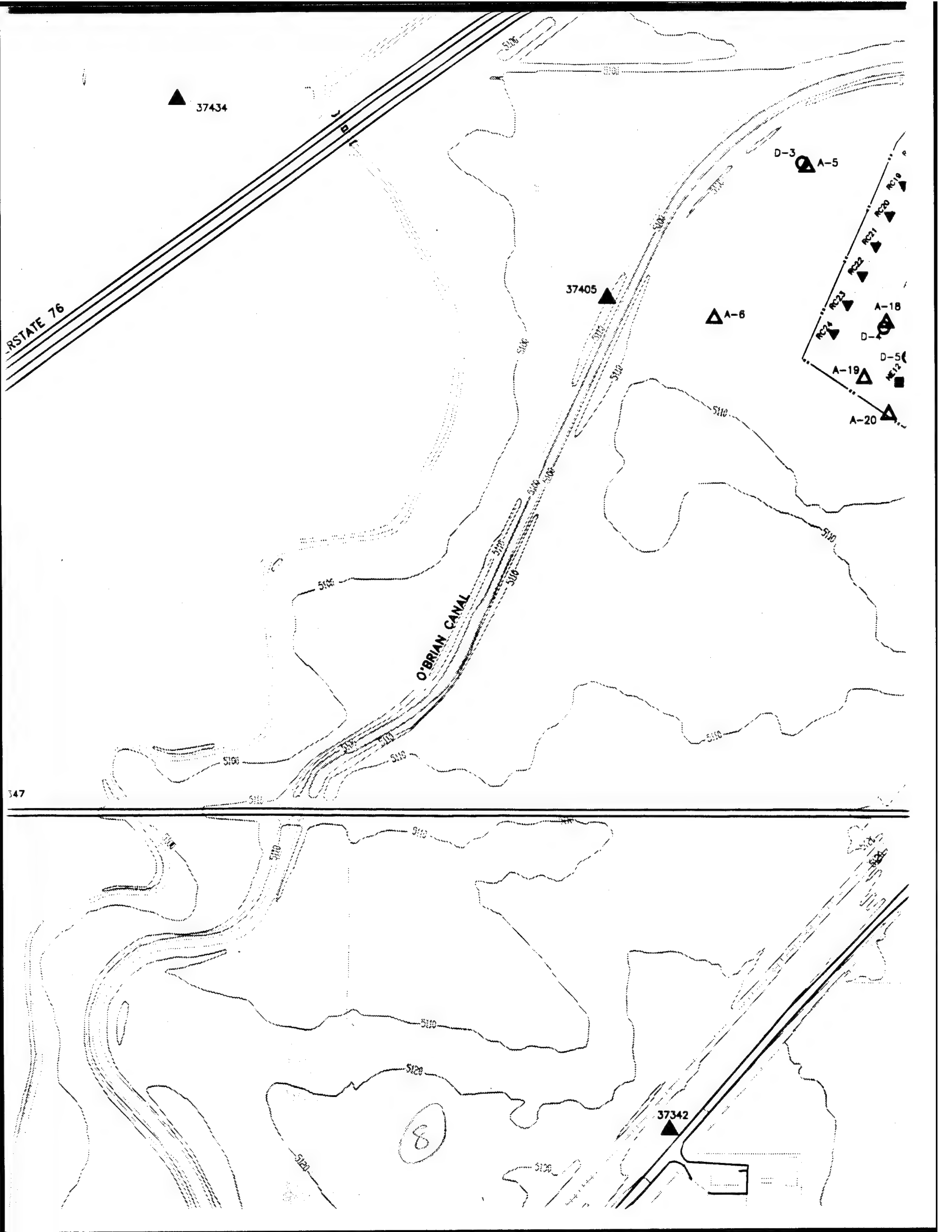

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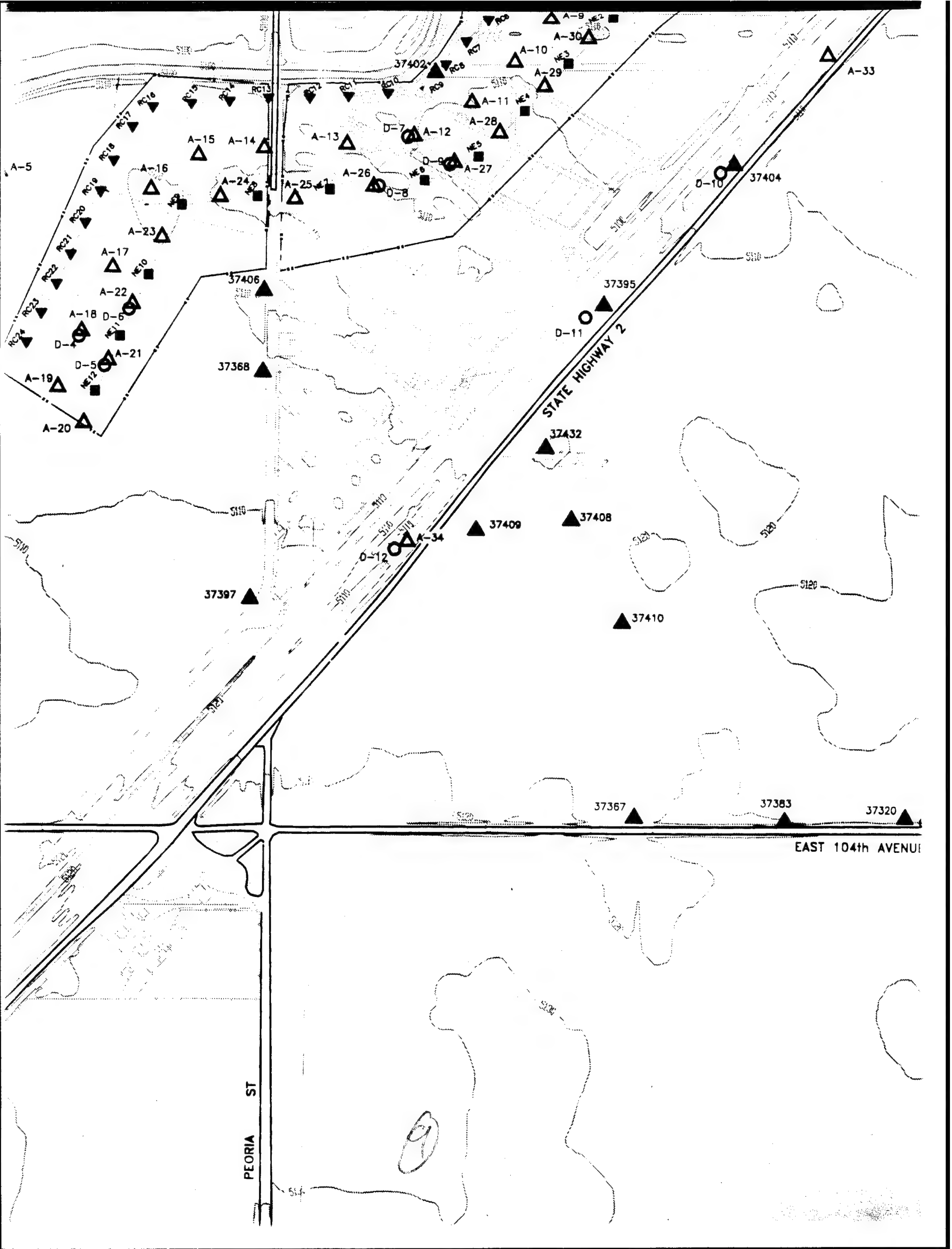

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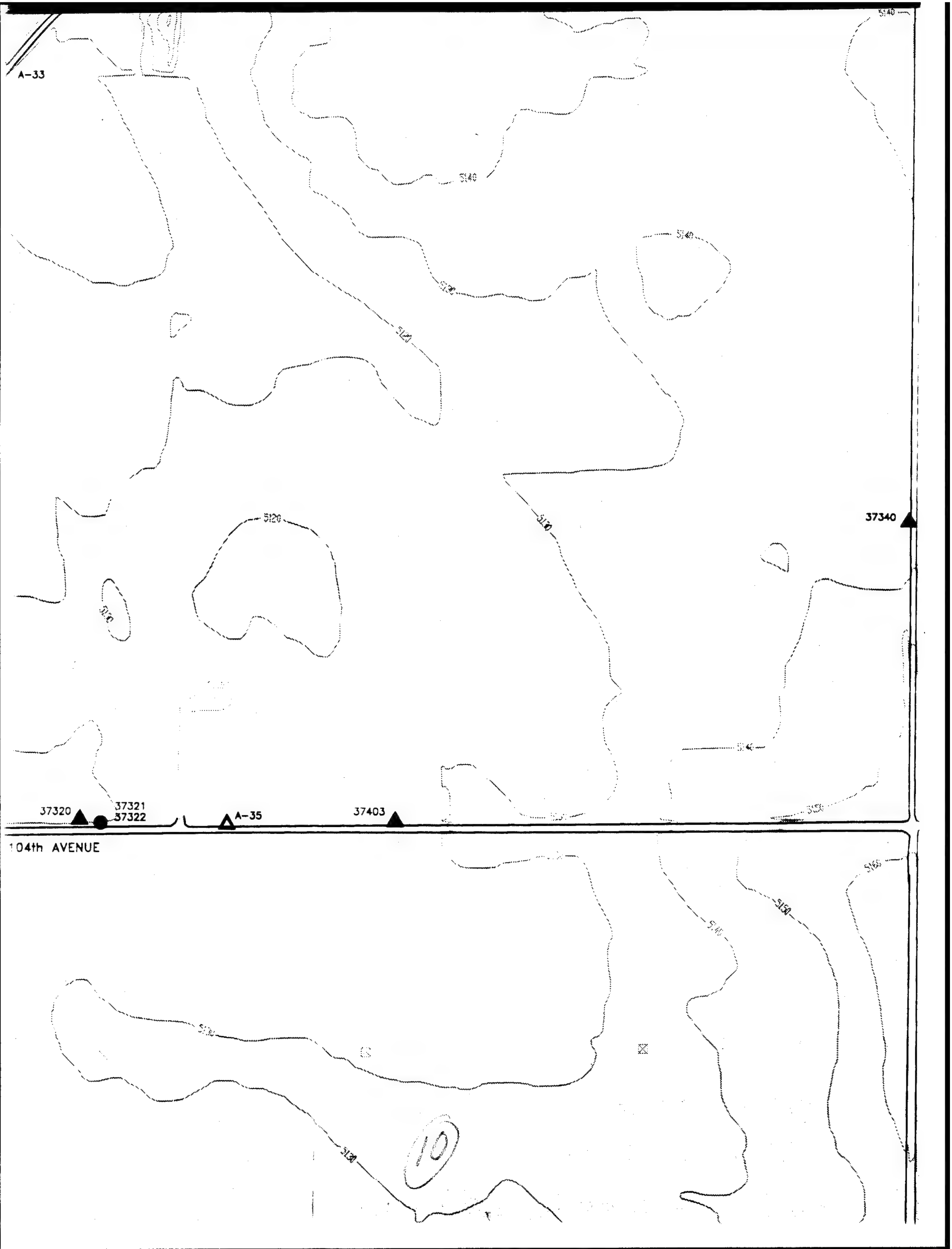

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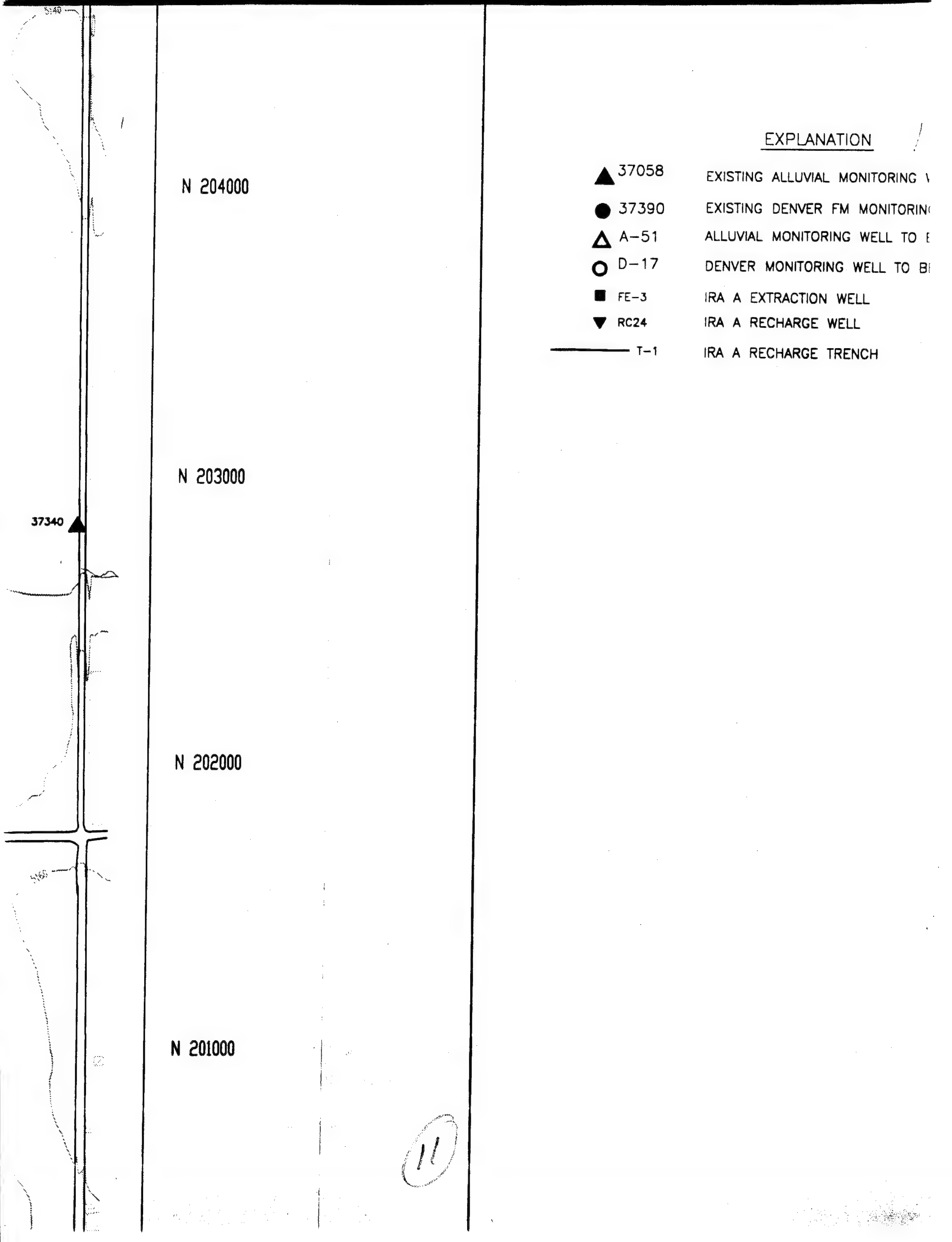
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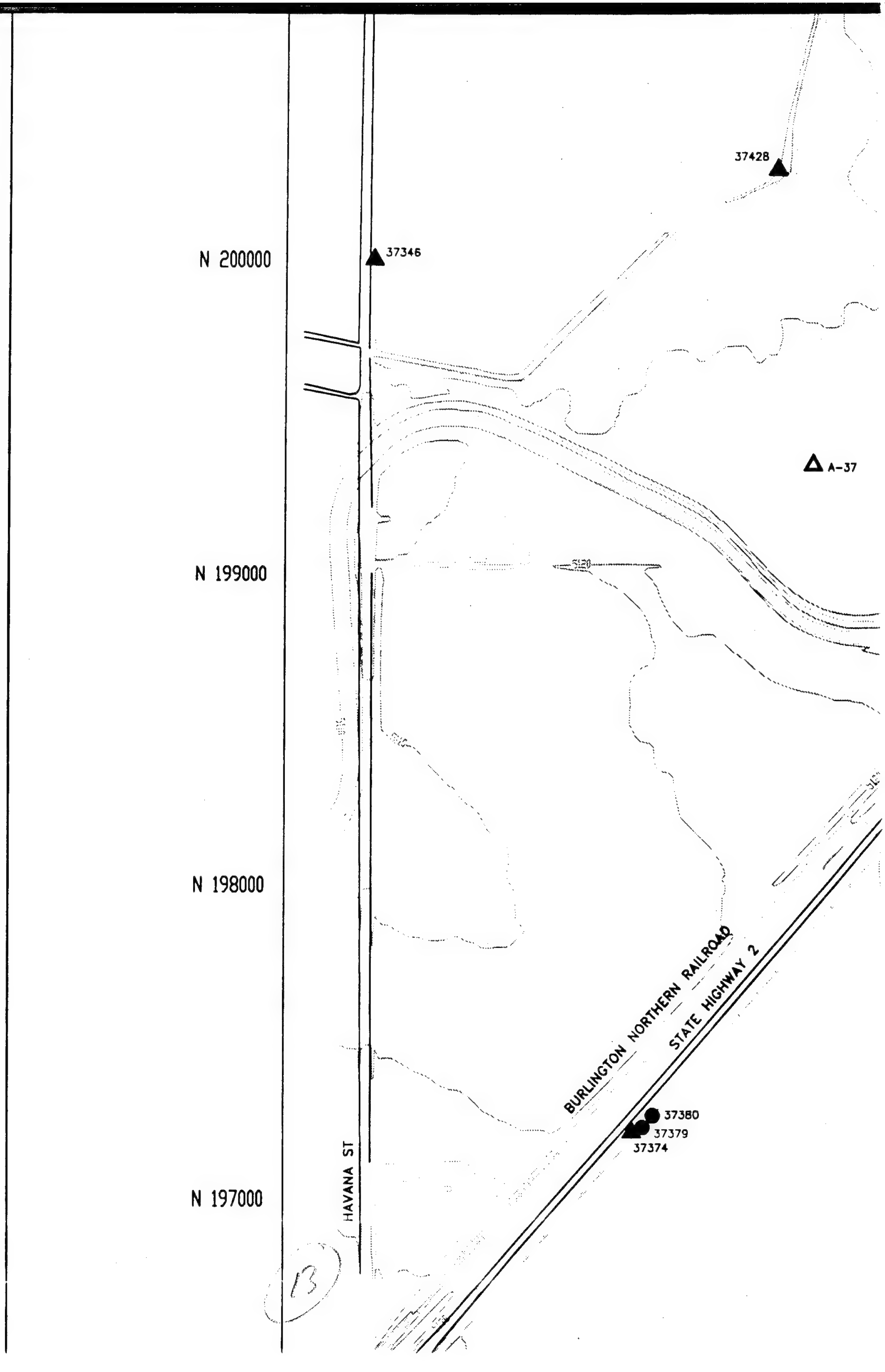

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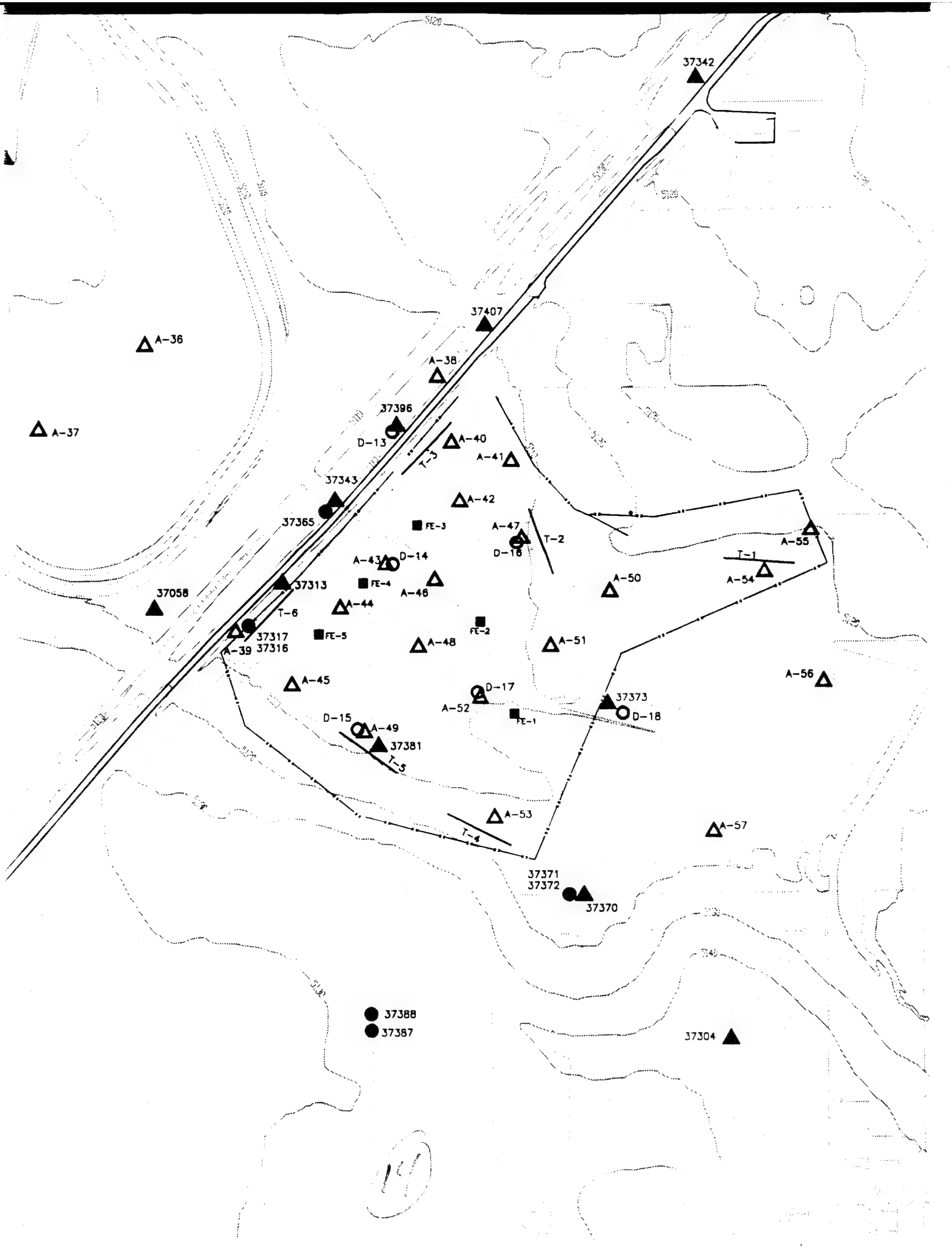

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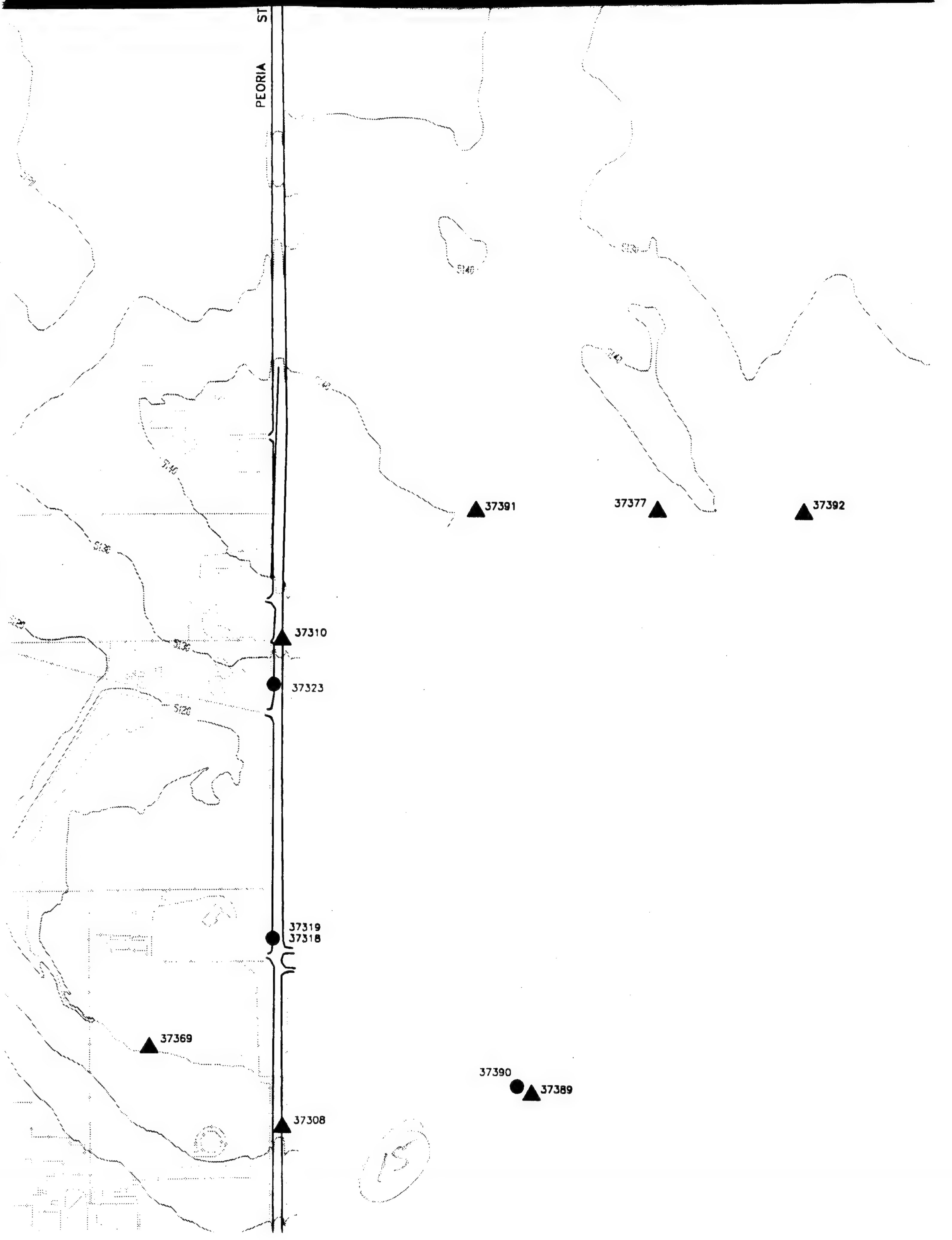

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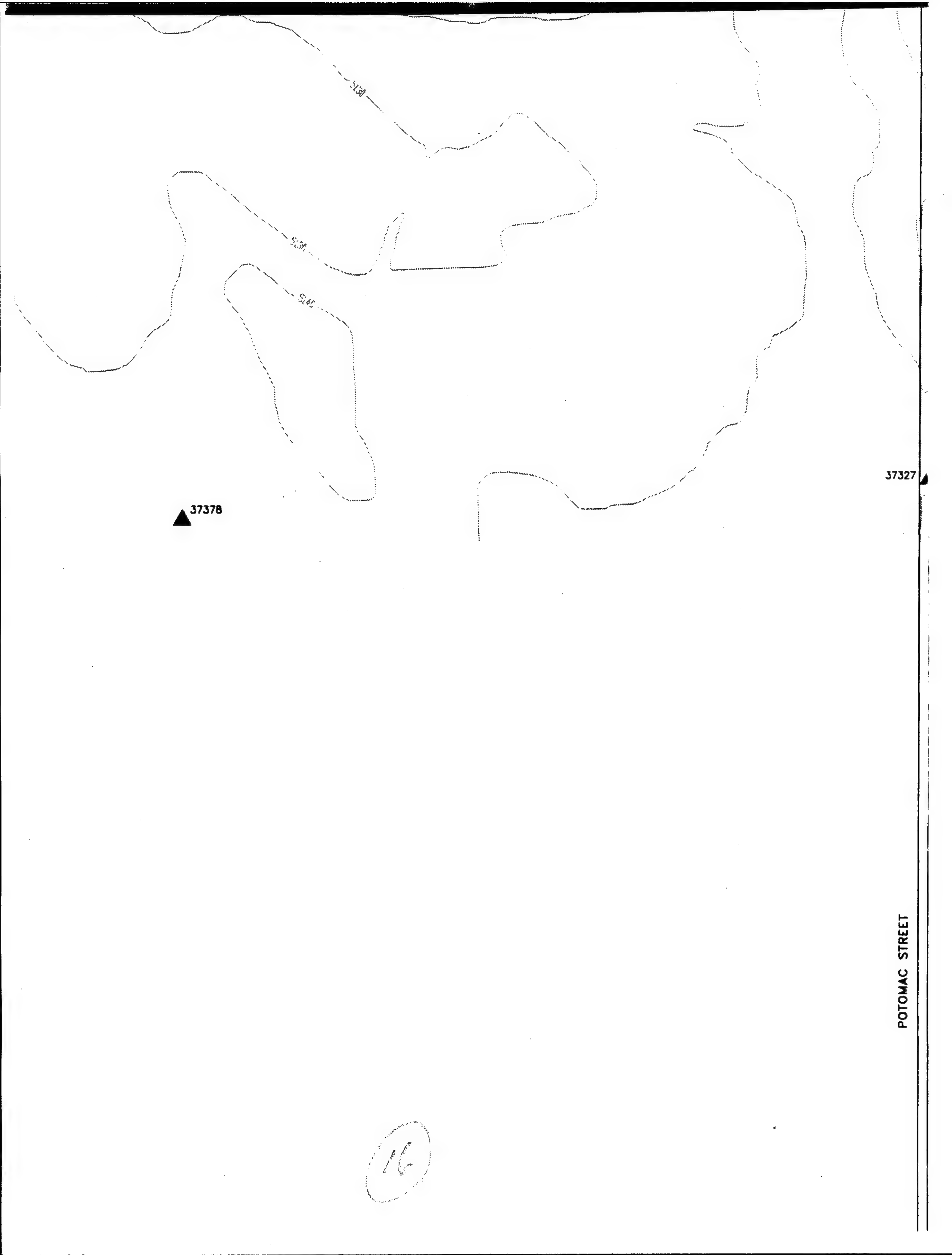

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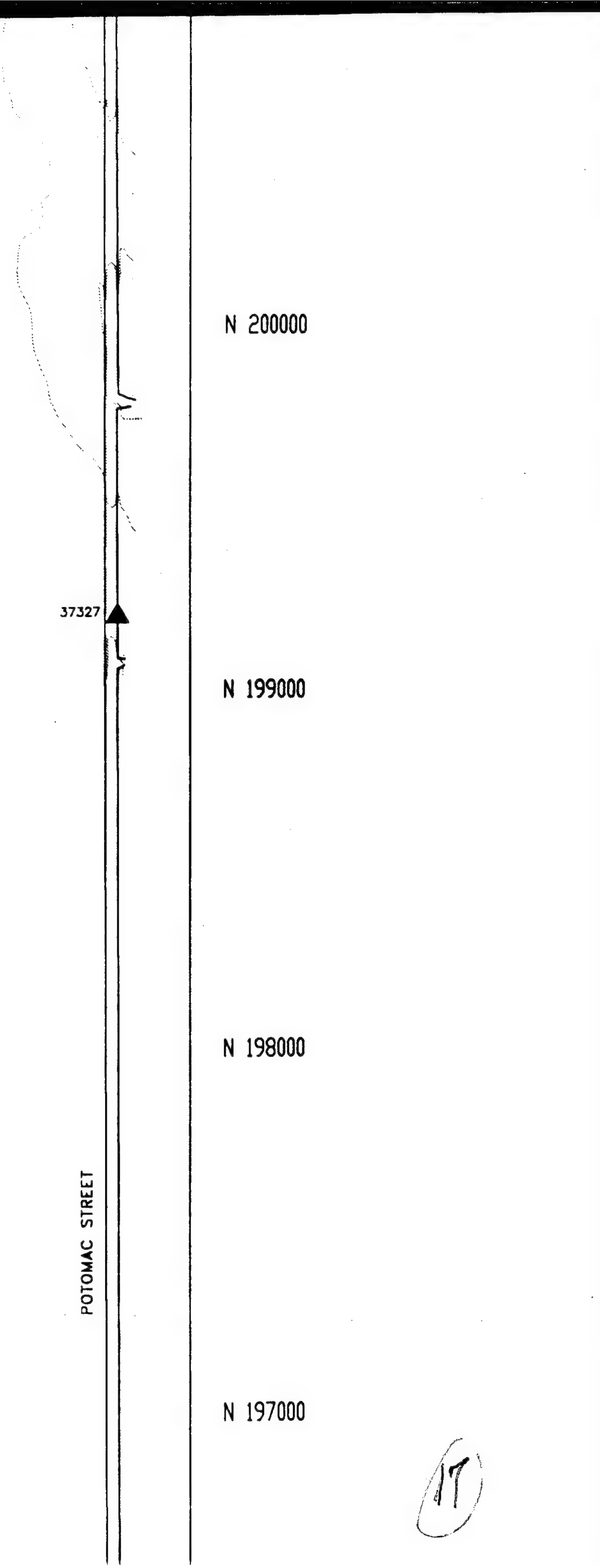

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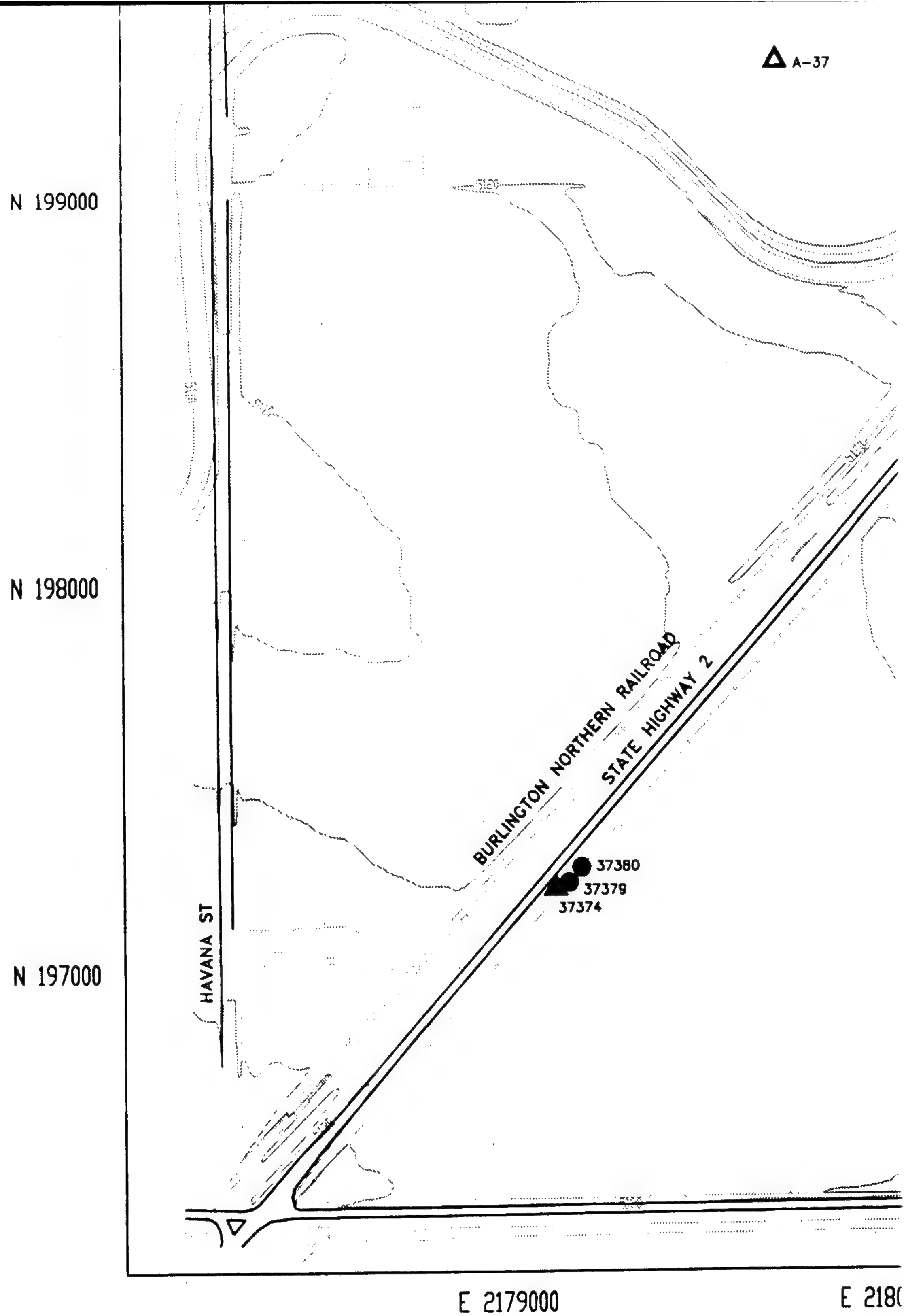

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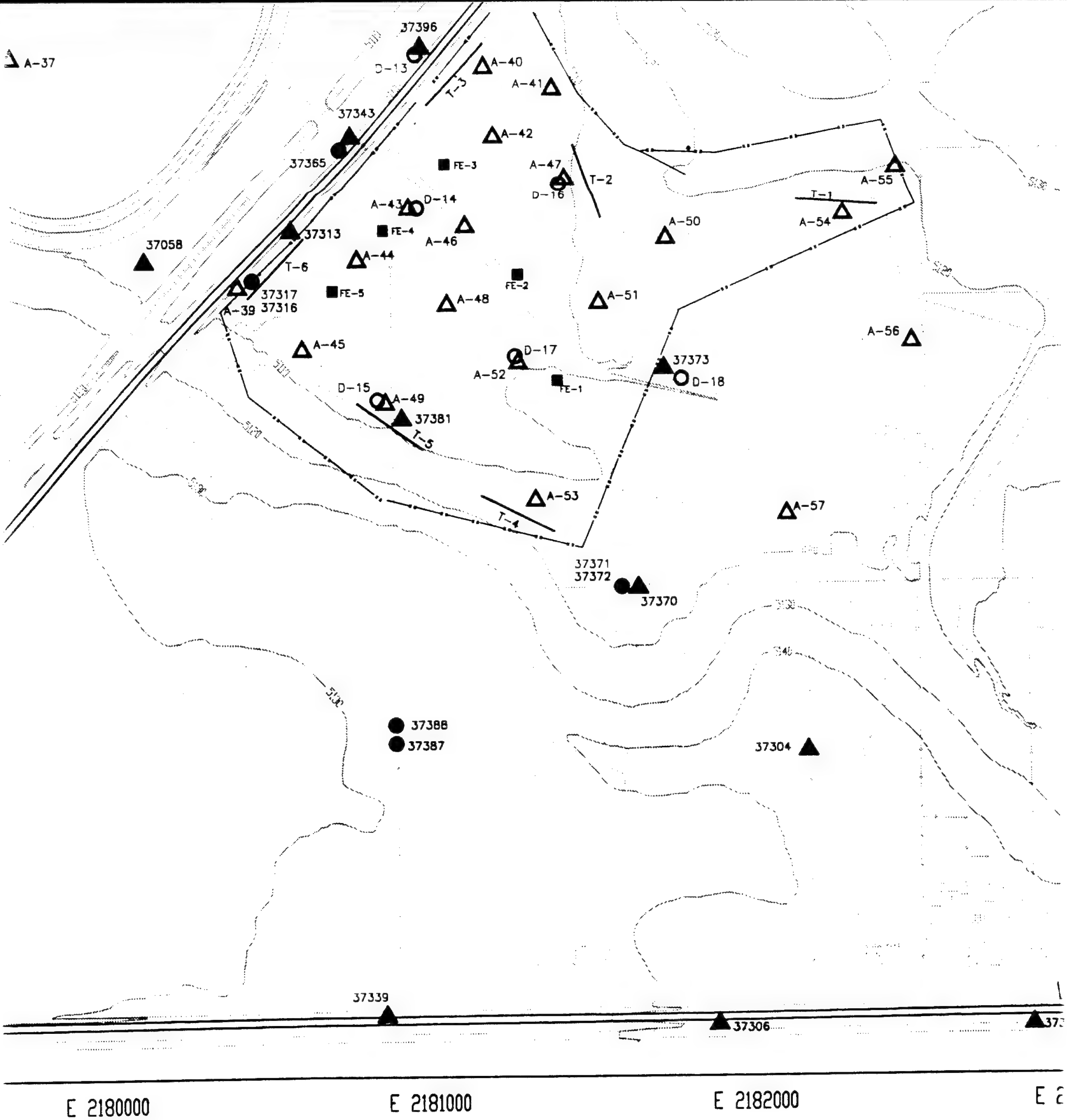
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E 2181000
E 2182000

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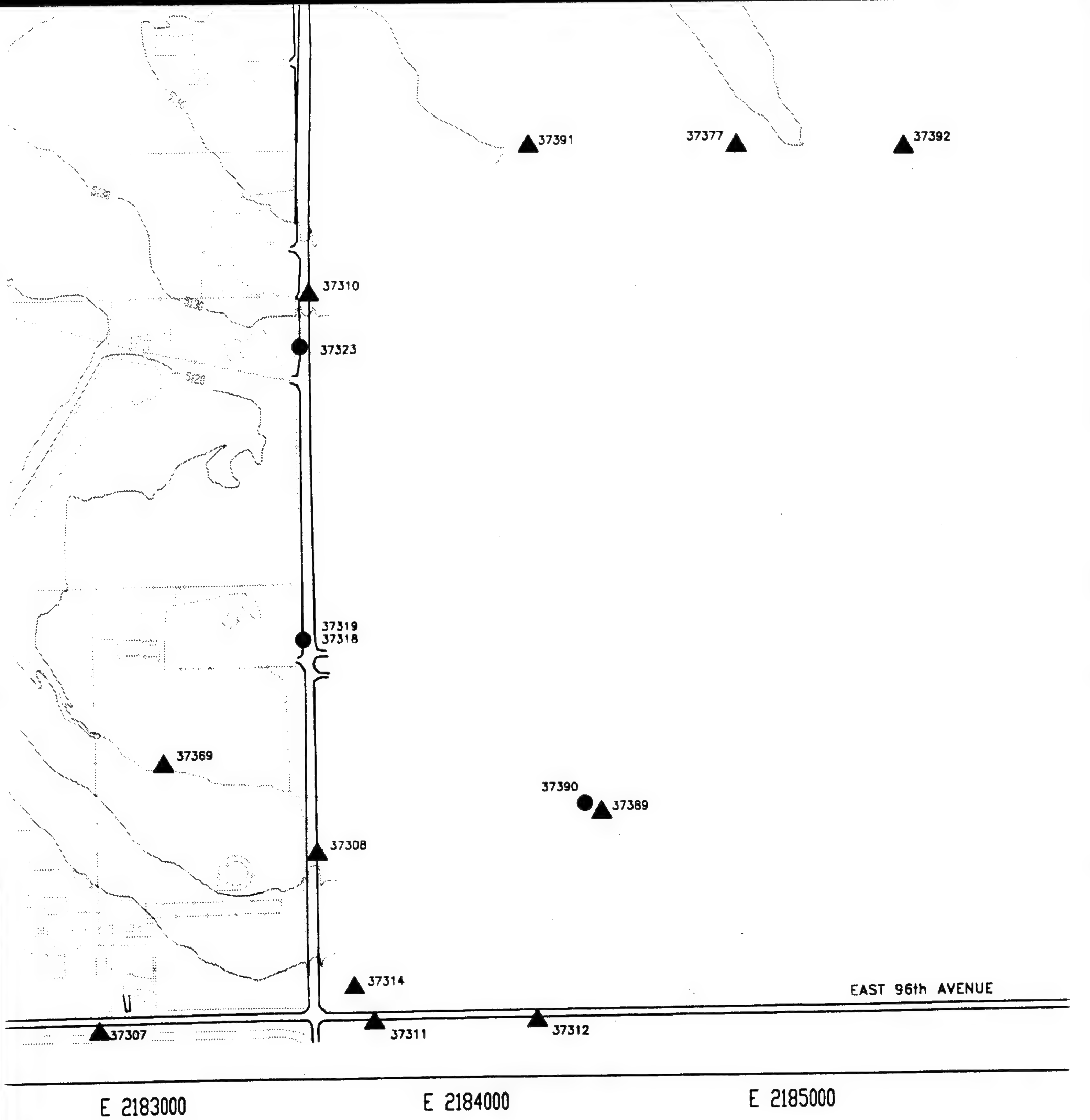
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E 2184000
E 2185000

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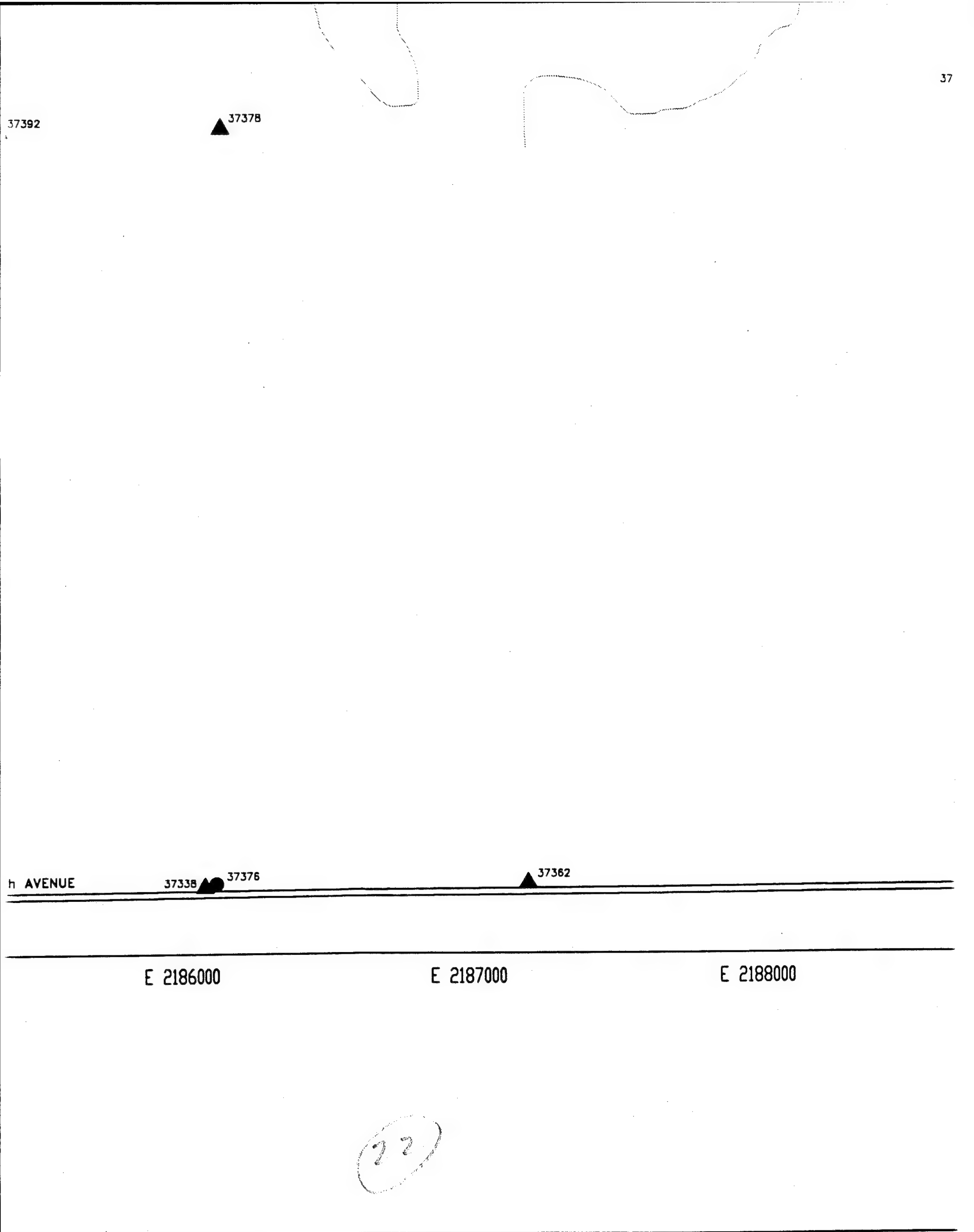

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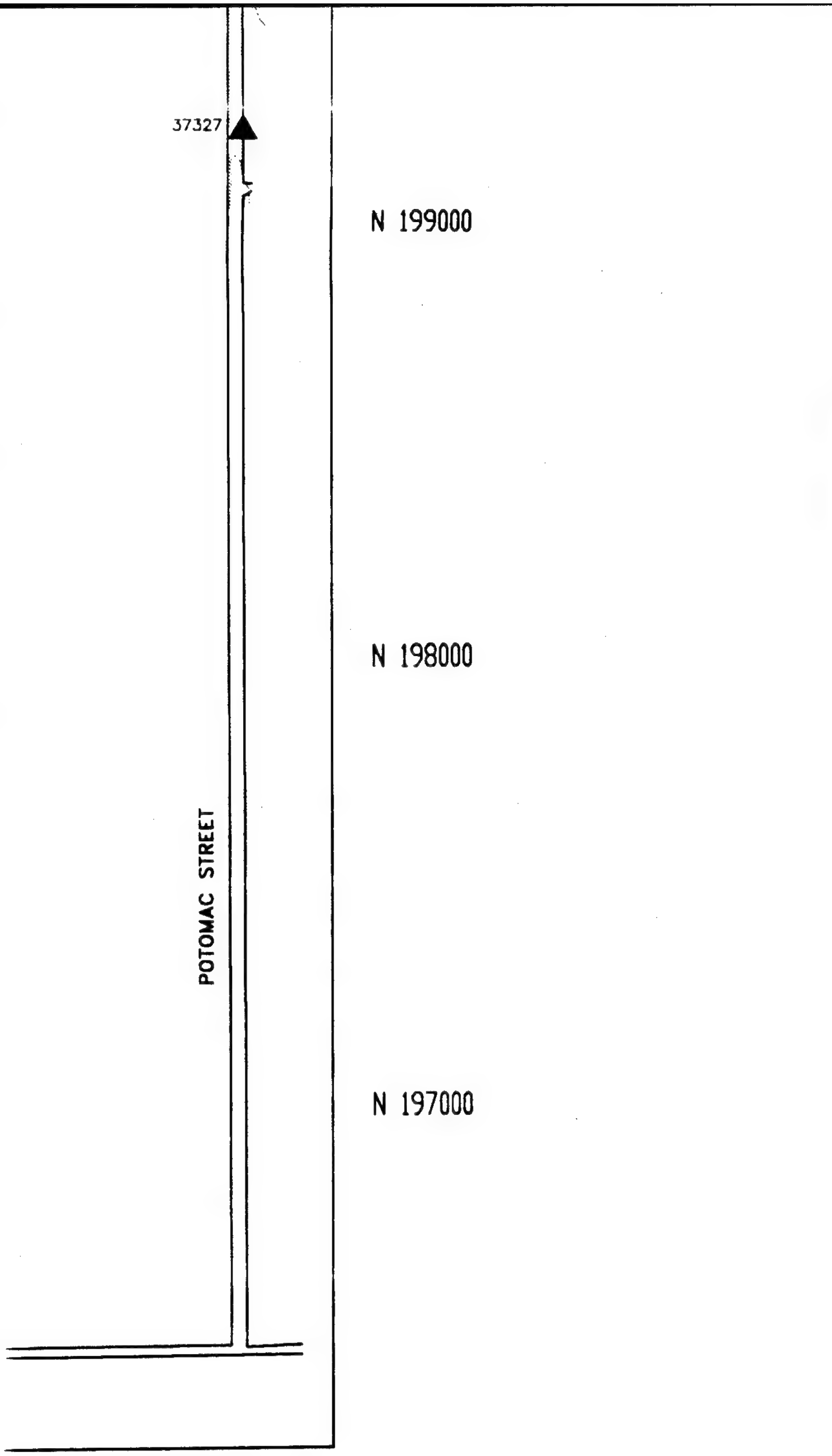

Prepared for:

U.S. Army Program M
for Rocky Mountain A

Commerce City, Color

PLATE 1

IRA A Monitoring Well

Prepared by: Harding
Associa

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Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

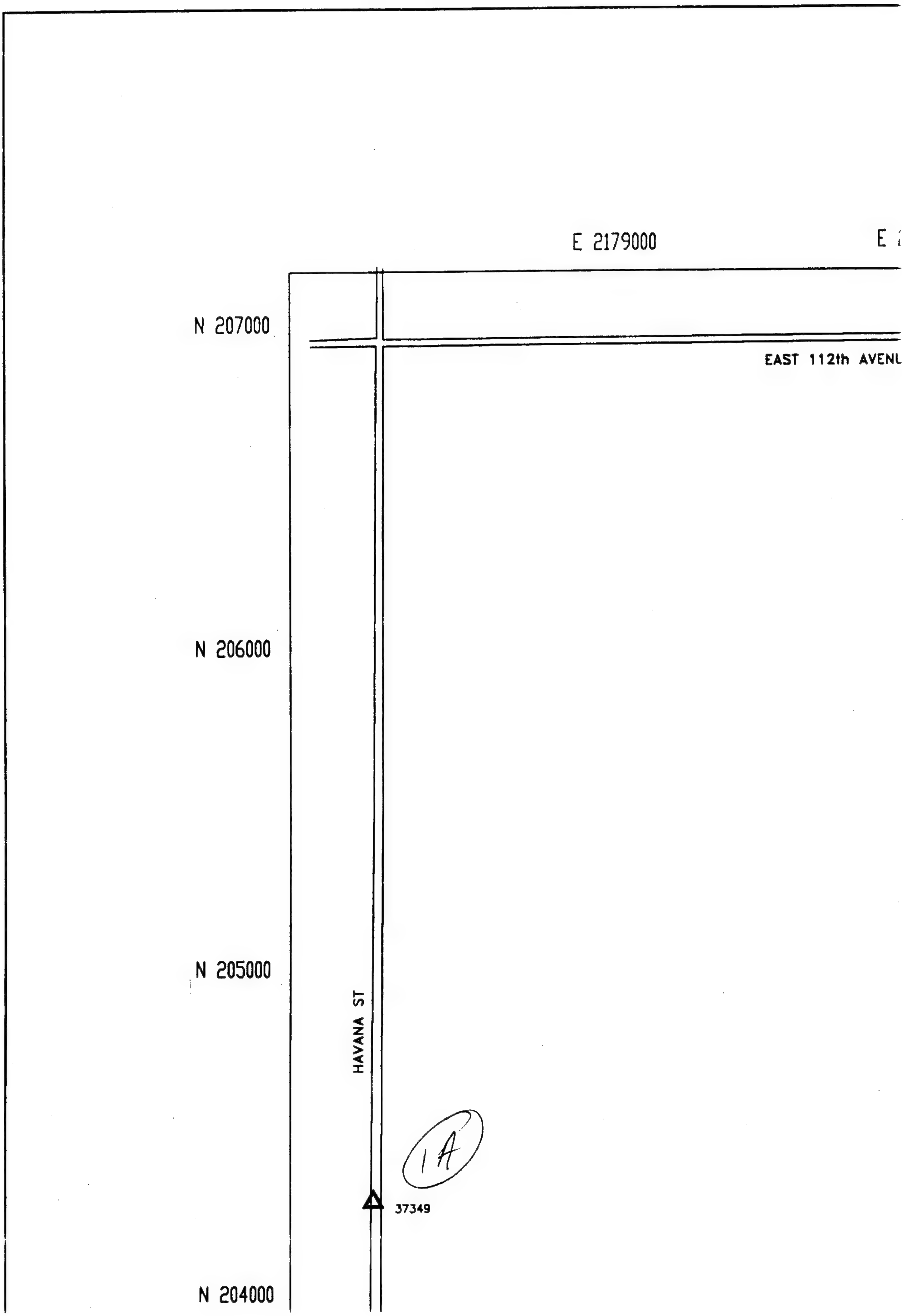
Commerce City, Colorado

PLATE 1

IRA A Monitoring Well Network

24

Prepared by: Harding Lawson Associates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N 205000
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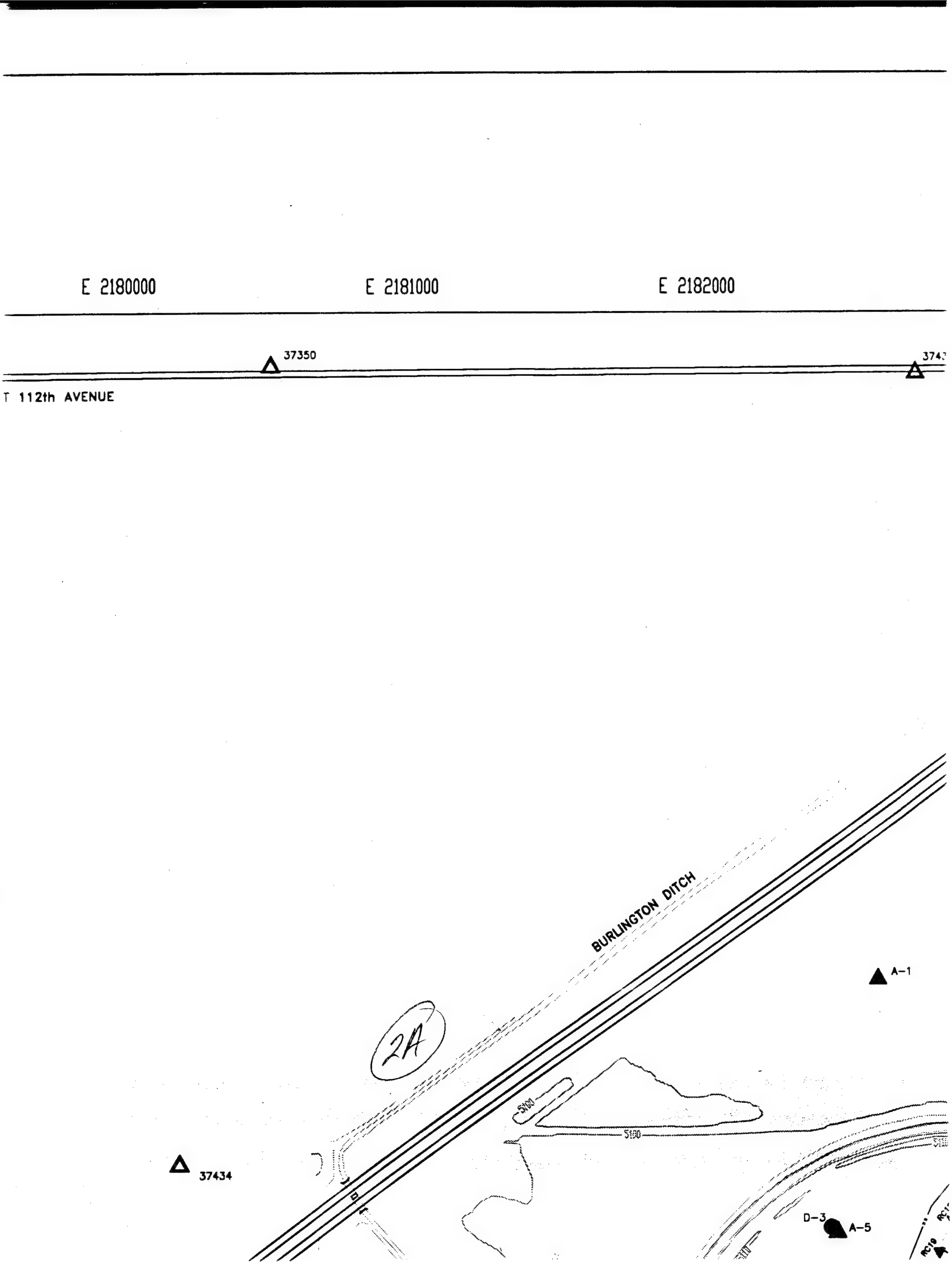
1A
37349
N 204000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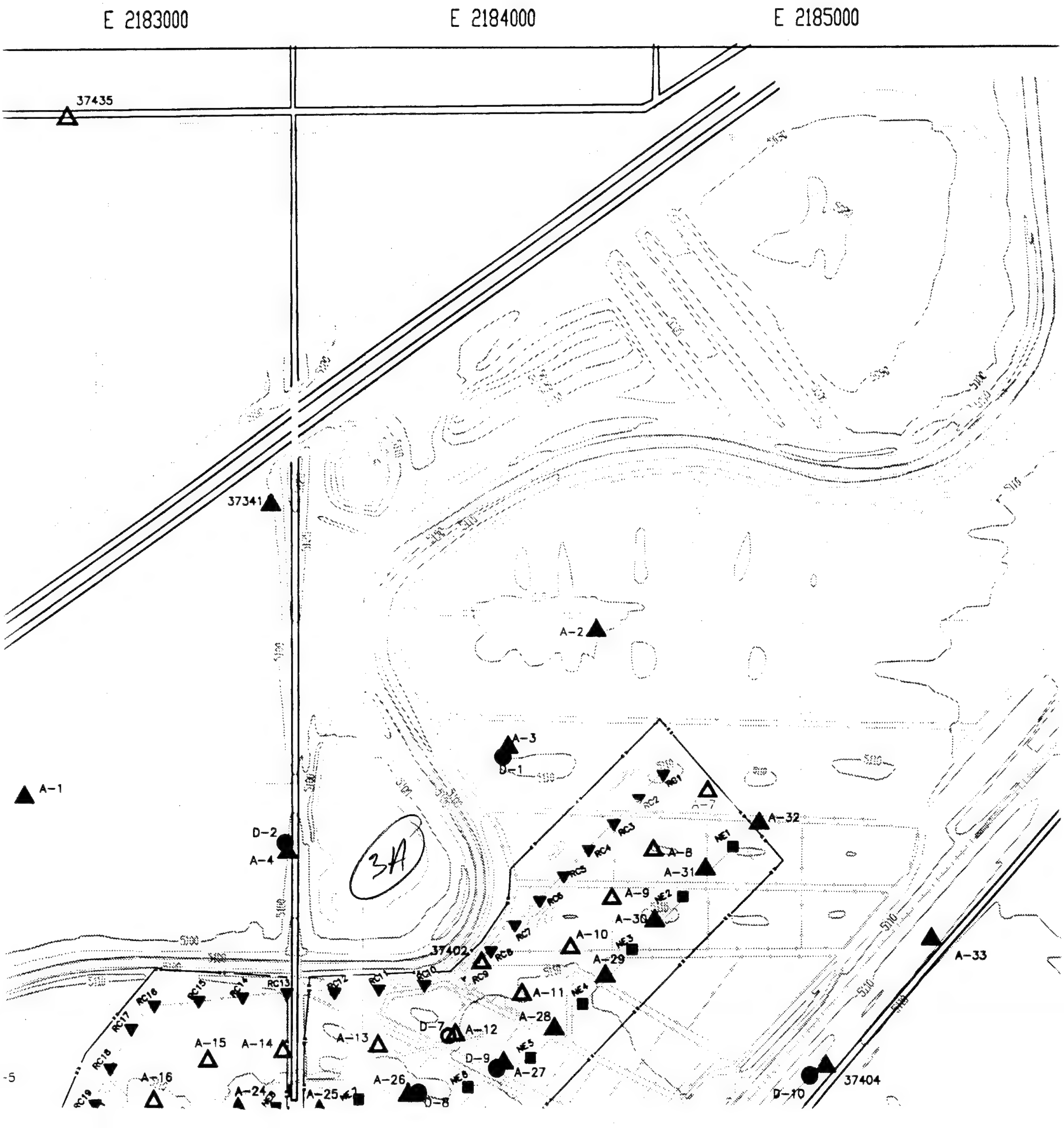
E 2181000
E 2182000
37350
T 112th AVENUE
BURLINGTON DITCH
2A
5100
5100
A-1
37434
D-3
A-5



E 2183000
E 2184000
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37435
37341
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A-1
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D-1
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A-4
3A
A-7
A-8
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A-11
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A-33
D-7
D-8
D-9
D-10
NE1
NE2
NE3
NE4
NE5
NE6
RC1
RC2
RC3
RC4
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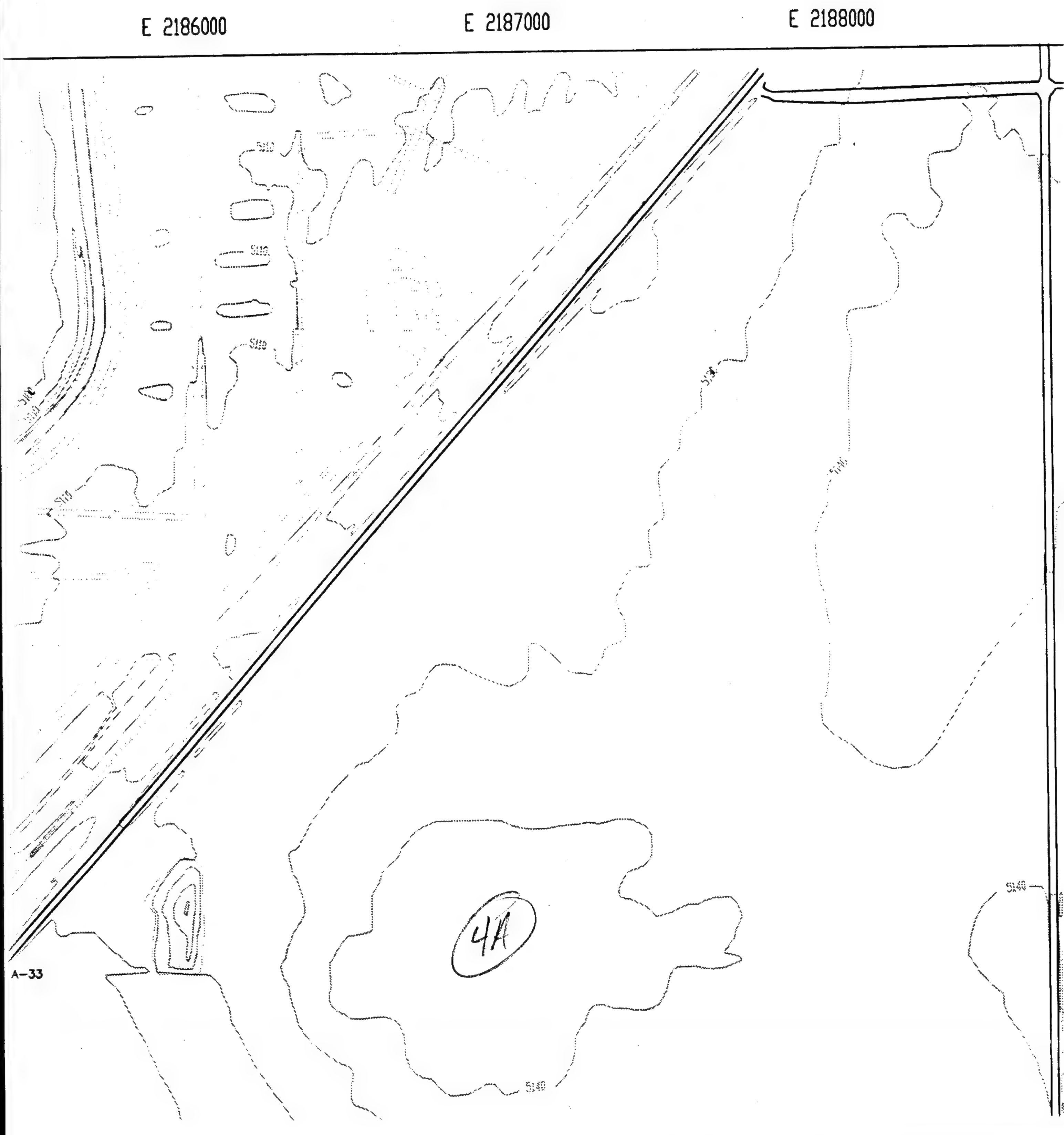
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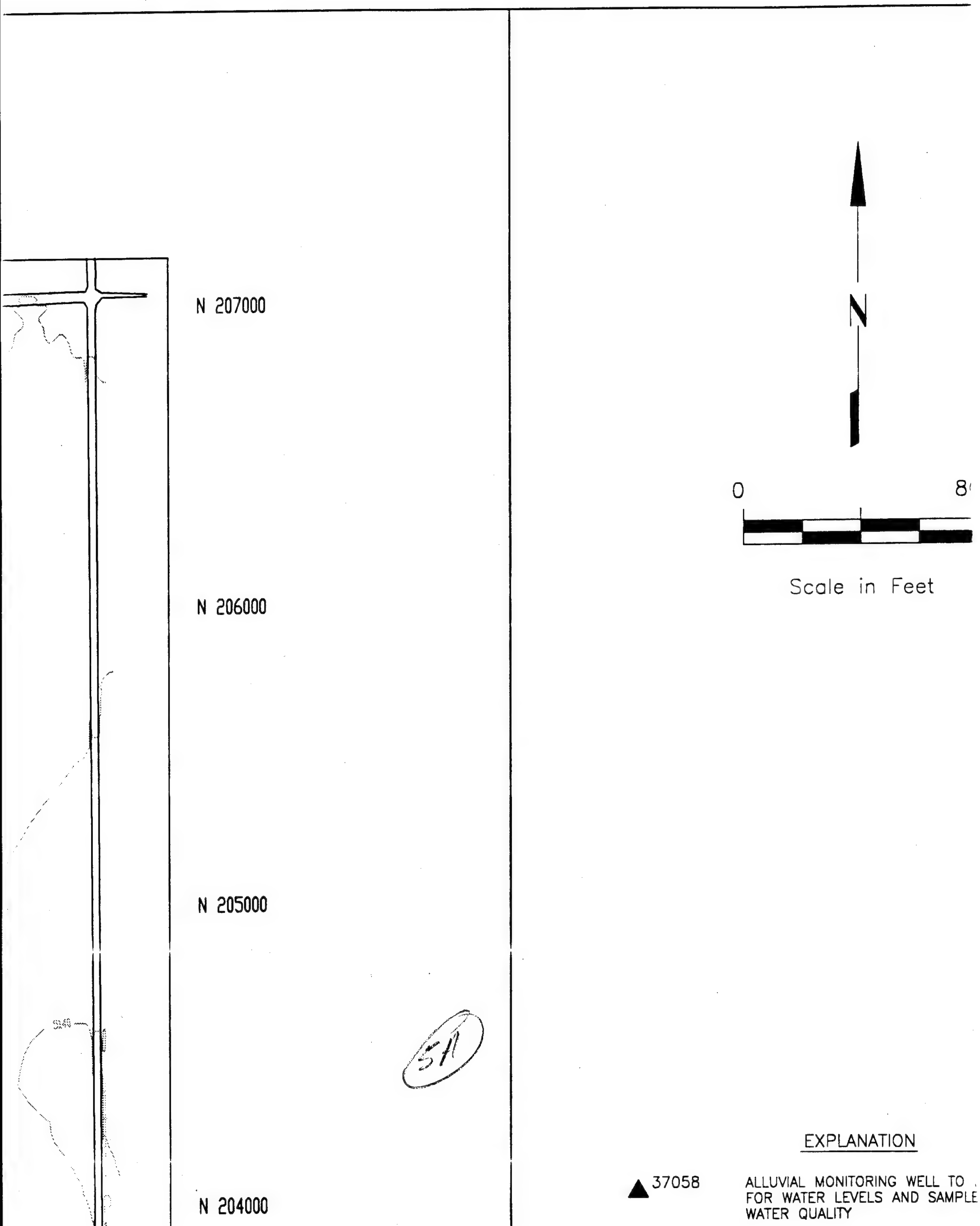
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N 204000
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Scale in Feet
EXPLANATION
37058
ALLUVIAL MONITORING WELL TO
FOR WATER LEVELS AND SAMPLE
WATER QUALITY

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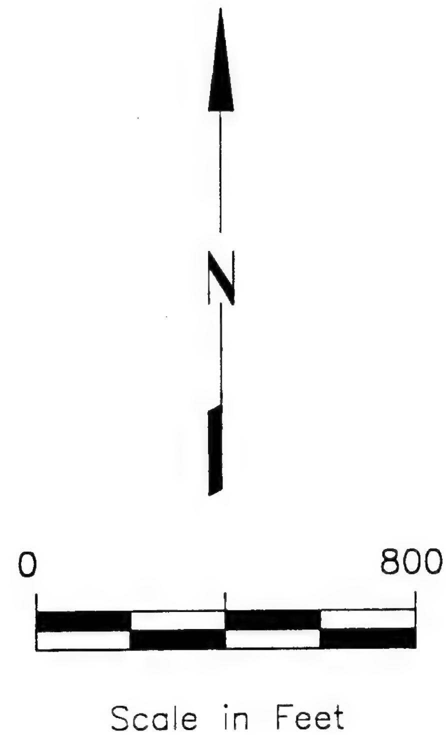

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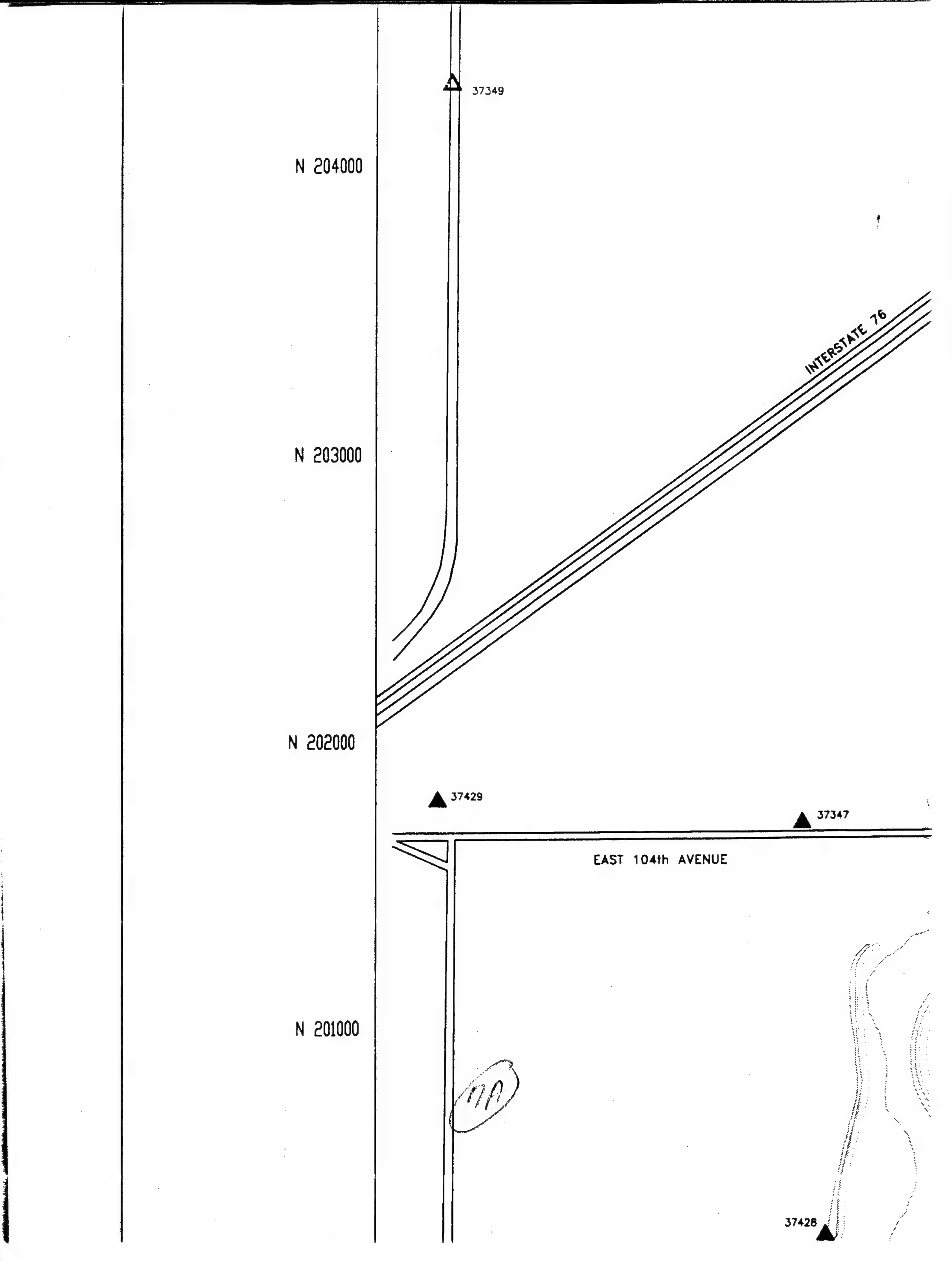
EXPLANATION

▲ 37058 — ALLUVIAL MONITORING WELL TO BE MEASURED FOR WATER LEVELS AND SAMPLED FOR WATER QUALITY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N 204000
N 203000
INTERSTATE 76
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37429
37347
EAST 104th AVENUE
N 201000
37428

37434
STATE 76
37405
A-6
D-3
A-5
RC19
RC20
RC21
RC22
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A-20
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5130
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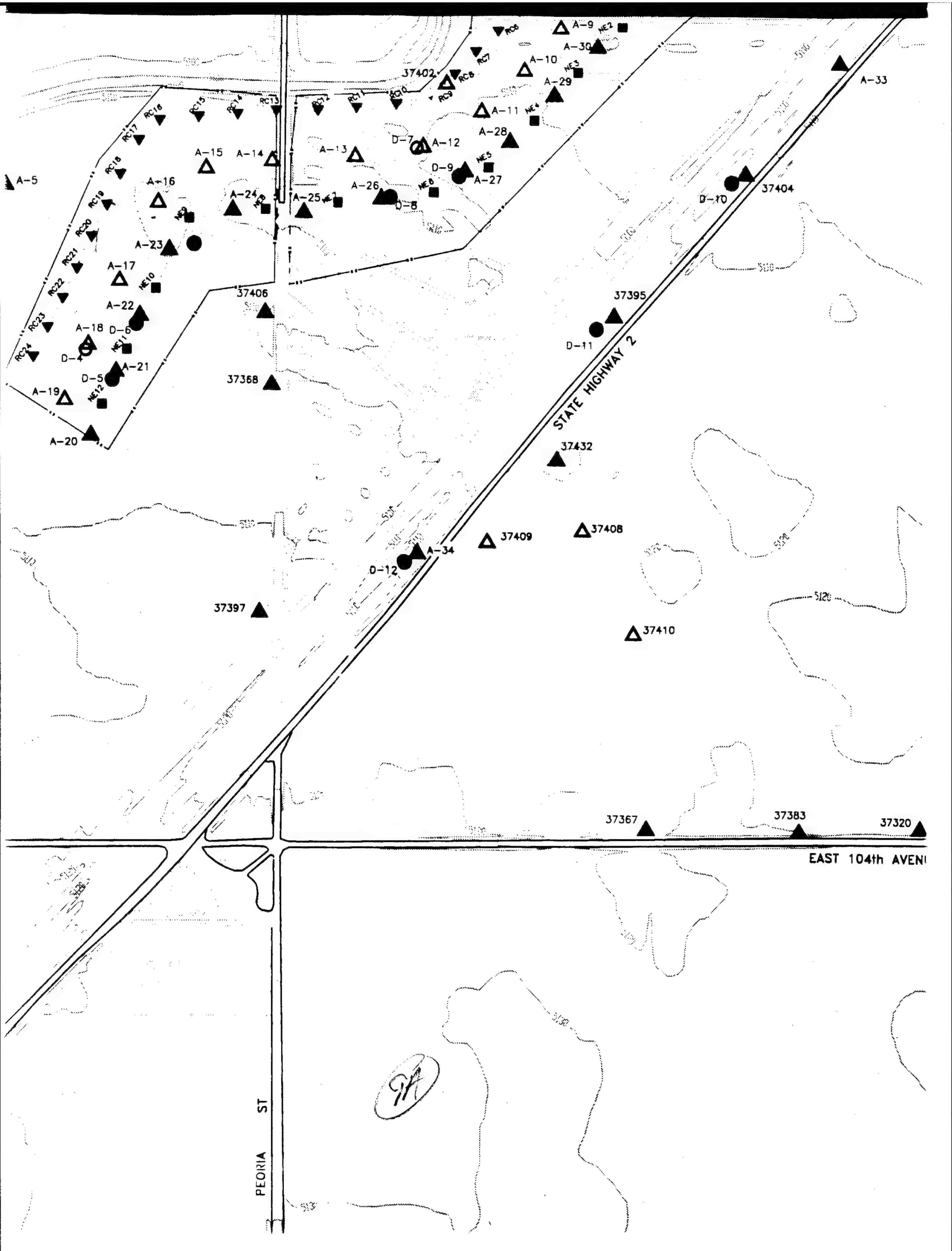

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37402
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37383
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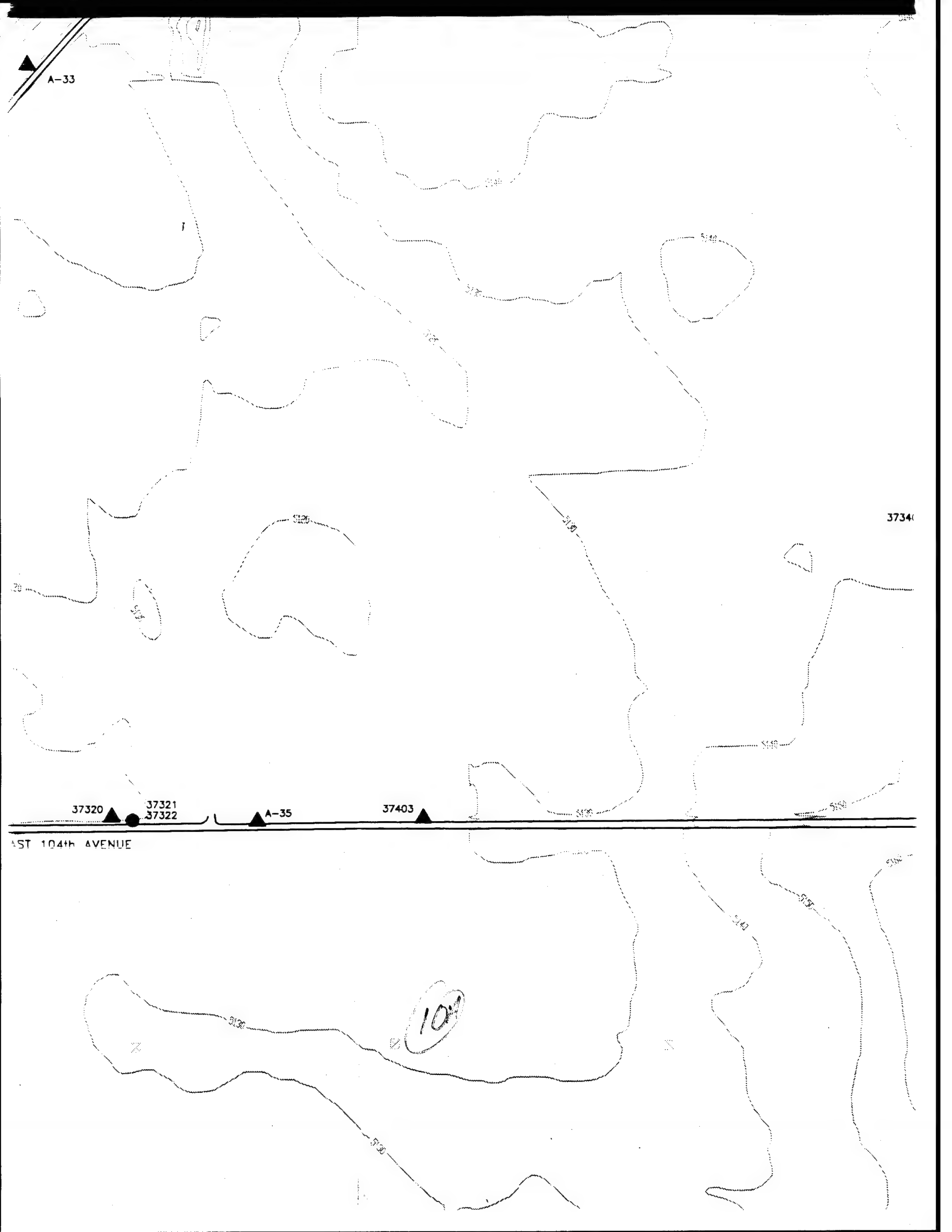
STATE HIGHWAY 2
EAST 104th AVENU
PEORIA ST



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AST 104th AVENUE
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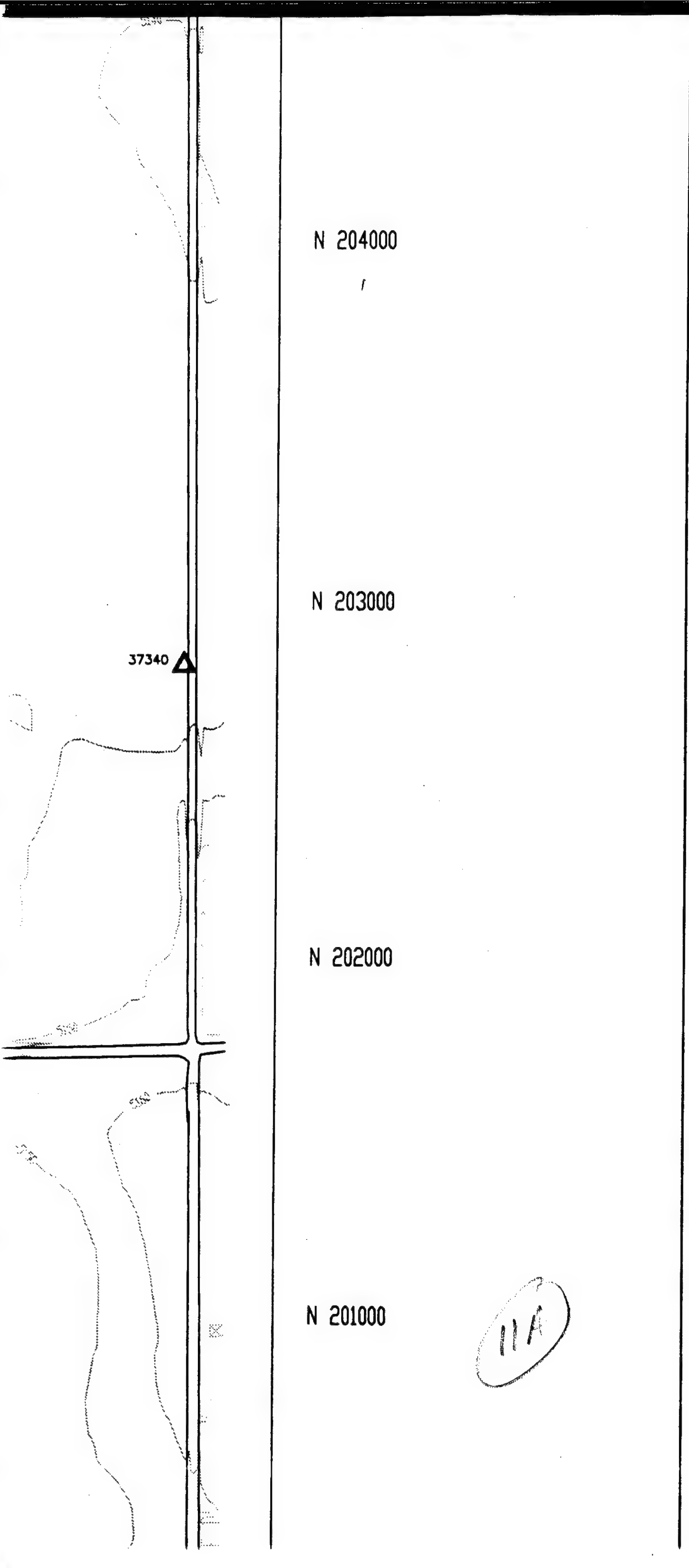

EXPLANATIO

▲	37058	ALLUVIAL MONITORING FOR WATER LEVELS AN WATER QUALITY
△	A-51	ALLUVIAL MONITORING FOR WATER LEVELS OI
●	37390	DENVER FM MONITORIN FOR WATER LEVELS AN WATER QUALITY
○	D-17	DENVER FM MONITORIN FOR WATER LEVELS OI
■	FE-3	IRA A EXTRACTION WEL
▼	RC24	IRA A RECHARGE WELL
——	T-1	IRA A RECHARGE TREN

04000

EXPLANATION

▲ 37058	ALLUVIAL MONITORING WELL TO BE MEASURED FOR WATER LEVELS AND SAMPLED FOR WATER QUALITY
△ A-51	ALLUVIAL MONITORING WELL TO BE MEASURED FOR WATER LEVELS ONLY
● 37390	DENVER FM MONITORING WELL TO BE MEASURED FOR WATER LEVELS AND SAMPLED FOR WATER QUALITY
○ D-17	DENVER FM MONITORING WELL TO BE MEASURED FOR WATER LEVELS ONLY
■ FE-3	IRA A EXTRACTION WELL
▼ RC24	IRA A RECHARGE WELL
——— T-1	IRA A RECHARGE TRENCH

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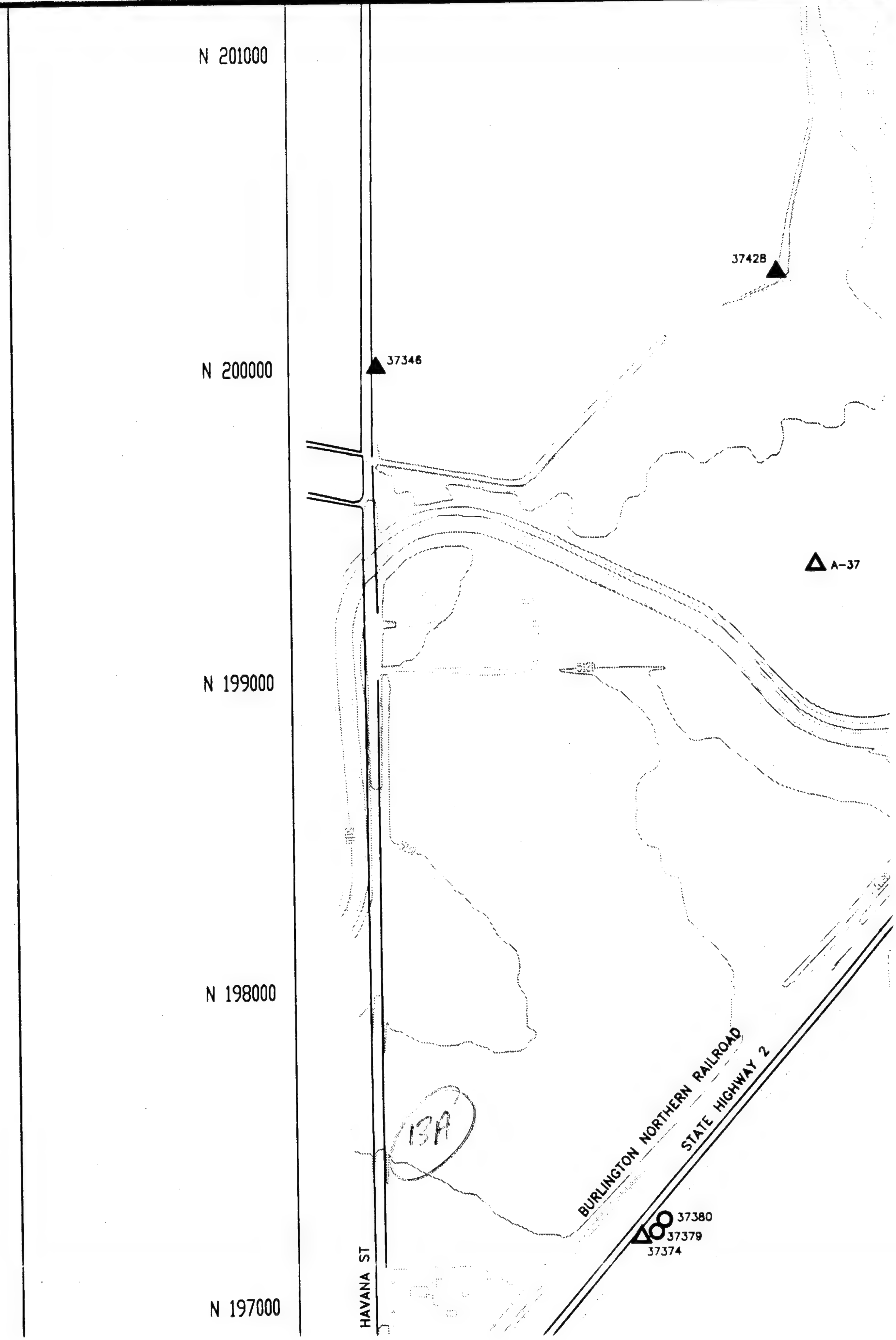
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N 200000
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A-37
N 199000
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13A
BURLINGTON NORTHERN RAILROAD
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37379
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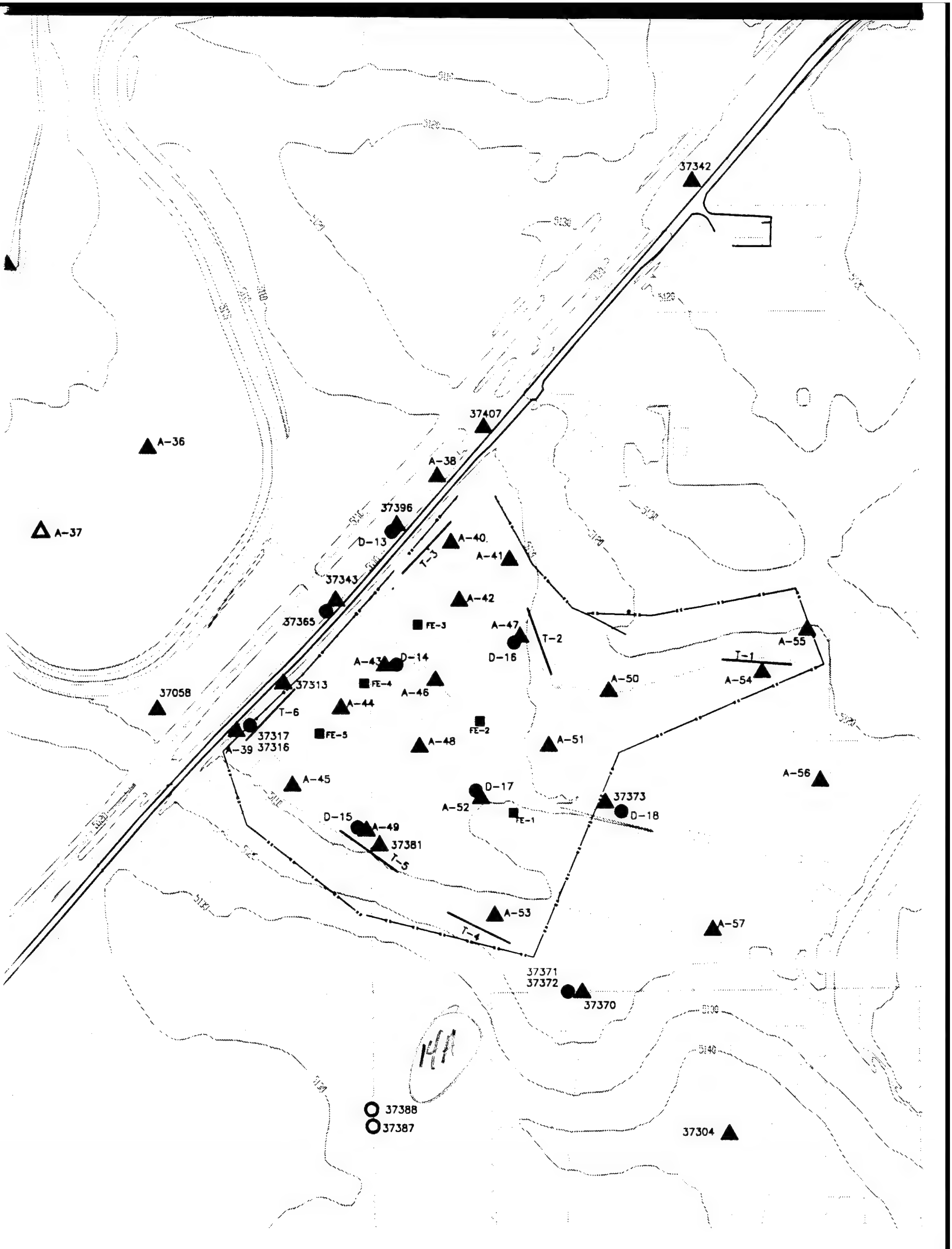
HAVANA ST
N 197000



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A-36
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A-40
A-41
T-3
37343
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FE-3
A-47
T-2
A-55
D-16
T-1
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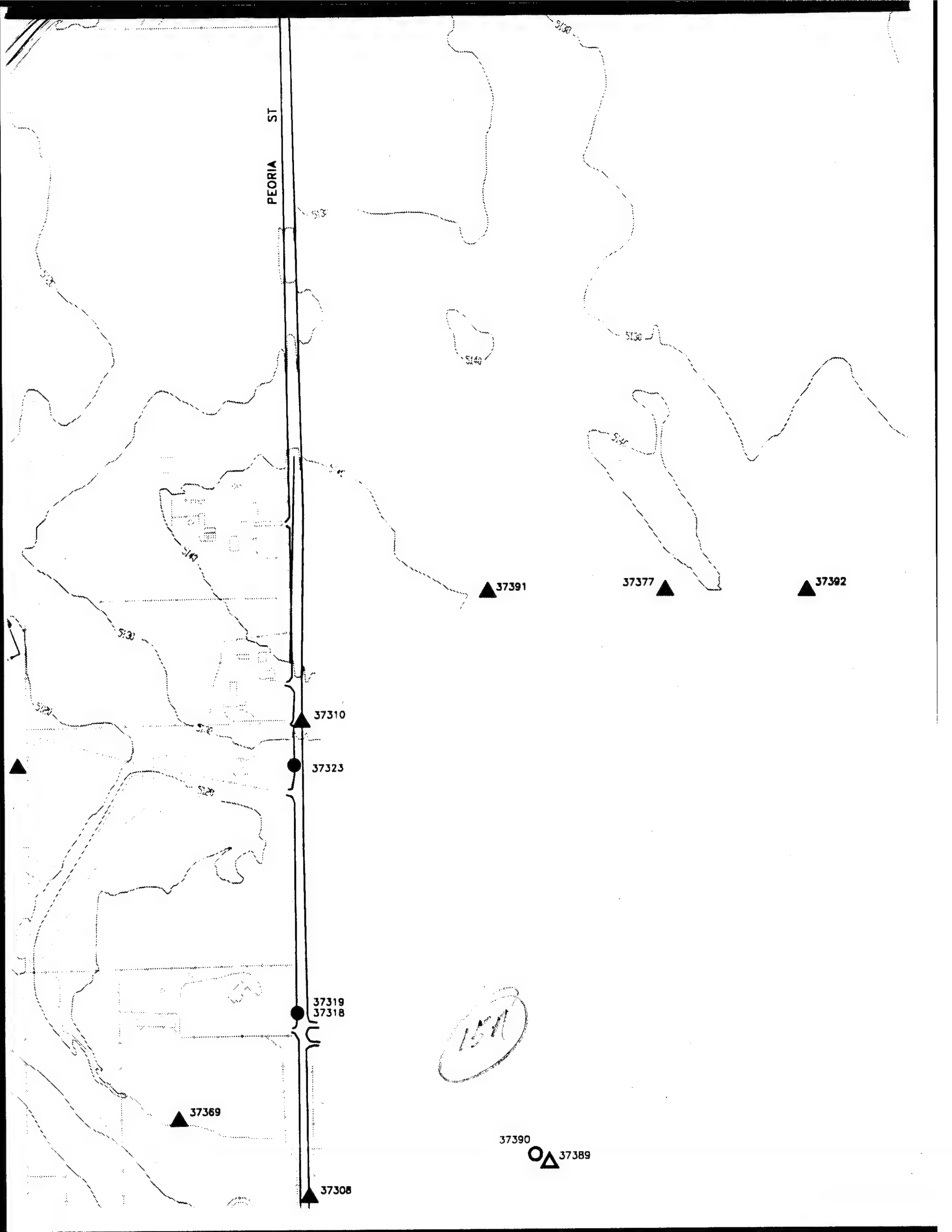

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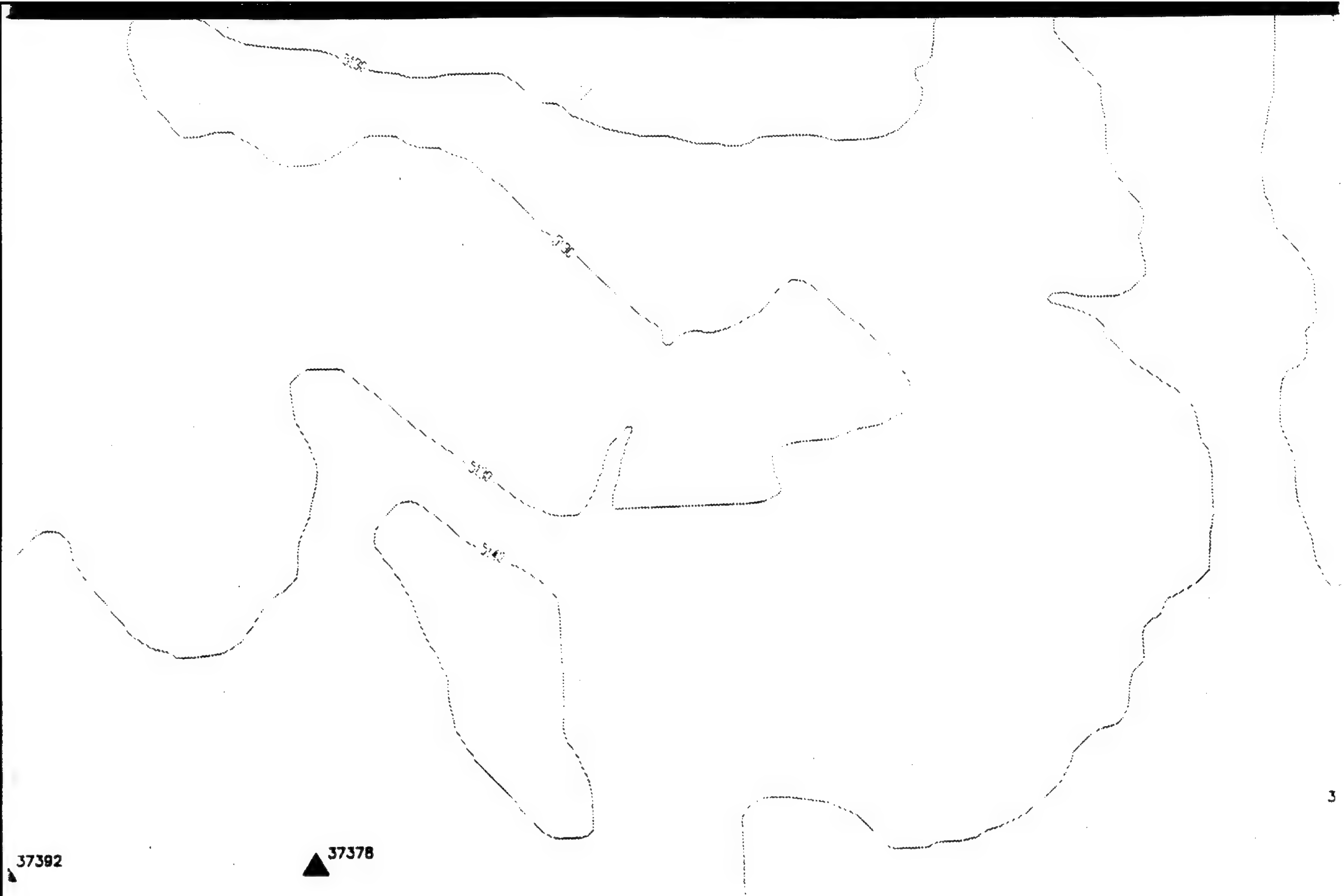

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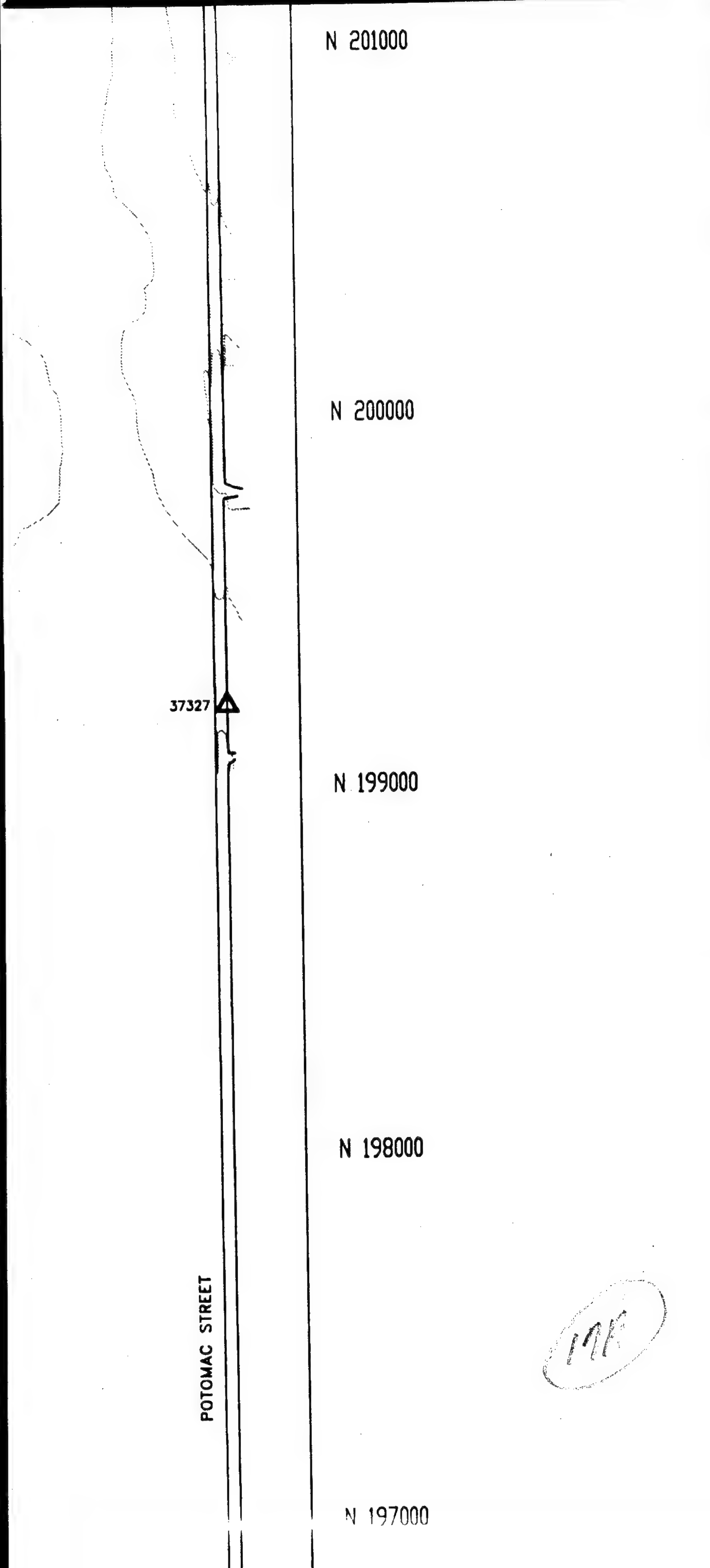

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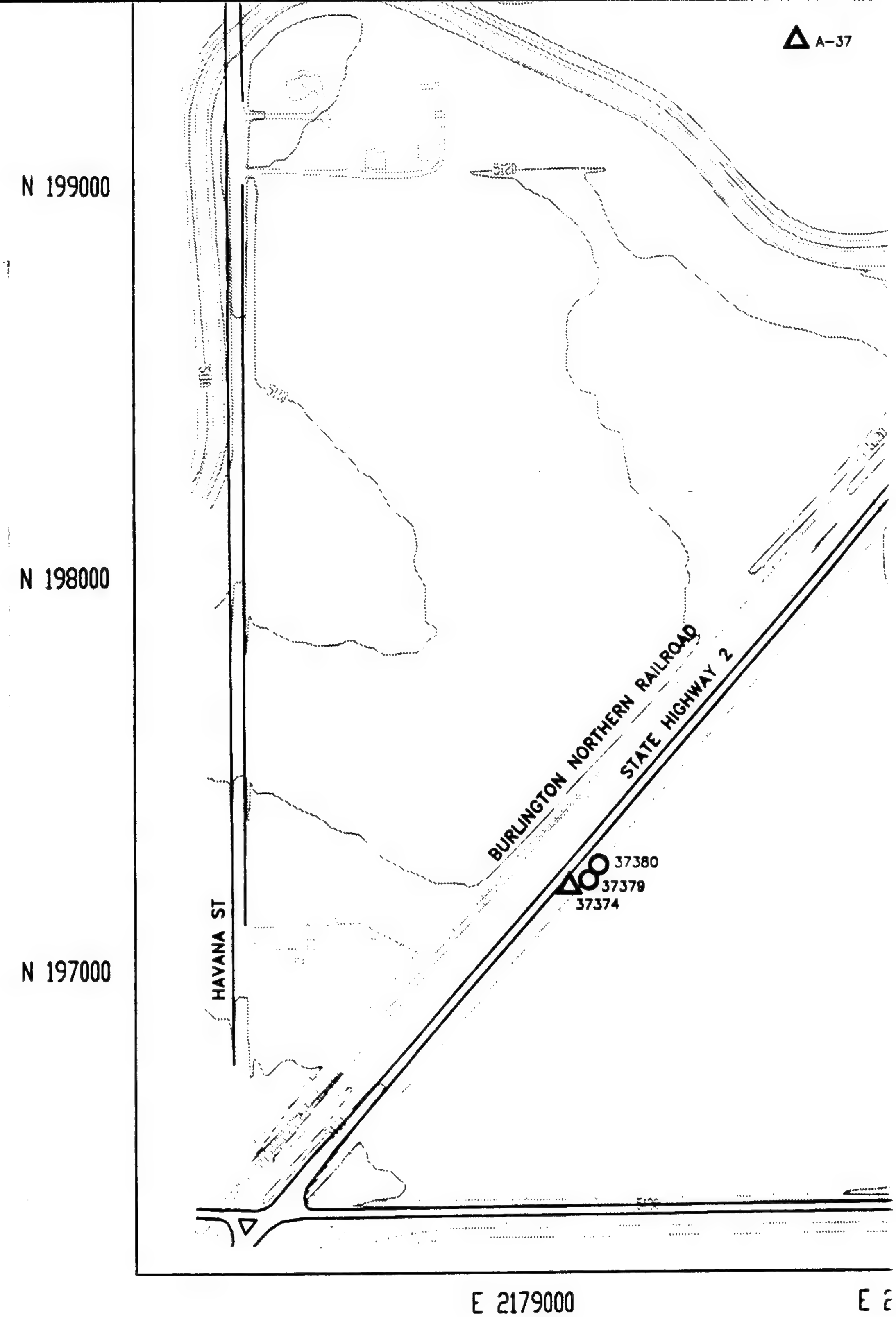
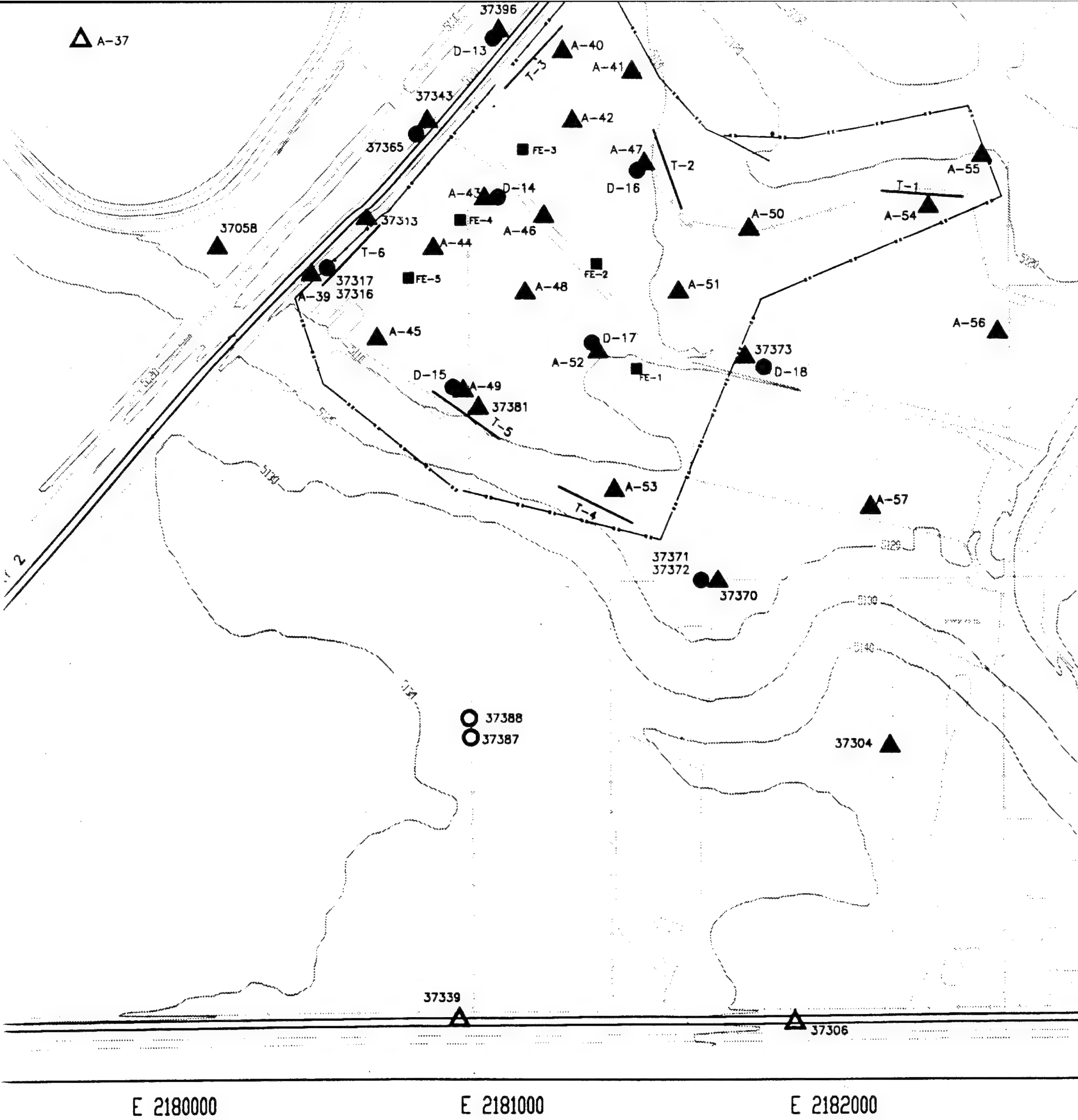


19A

RMA\RMABASE1 2/12/92 TAG



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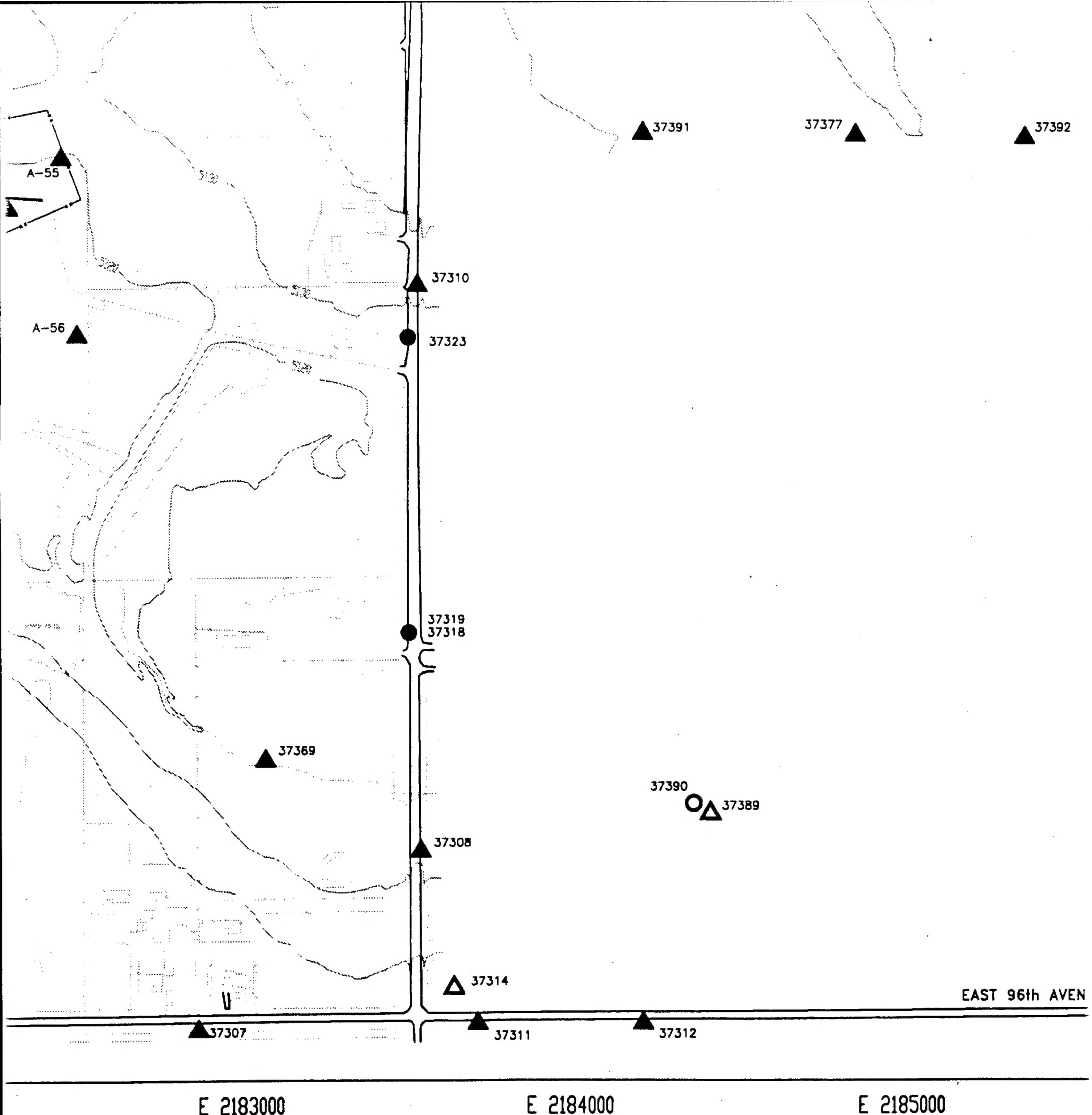

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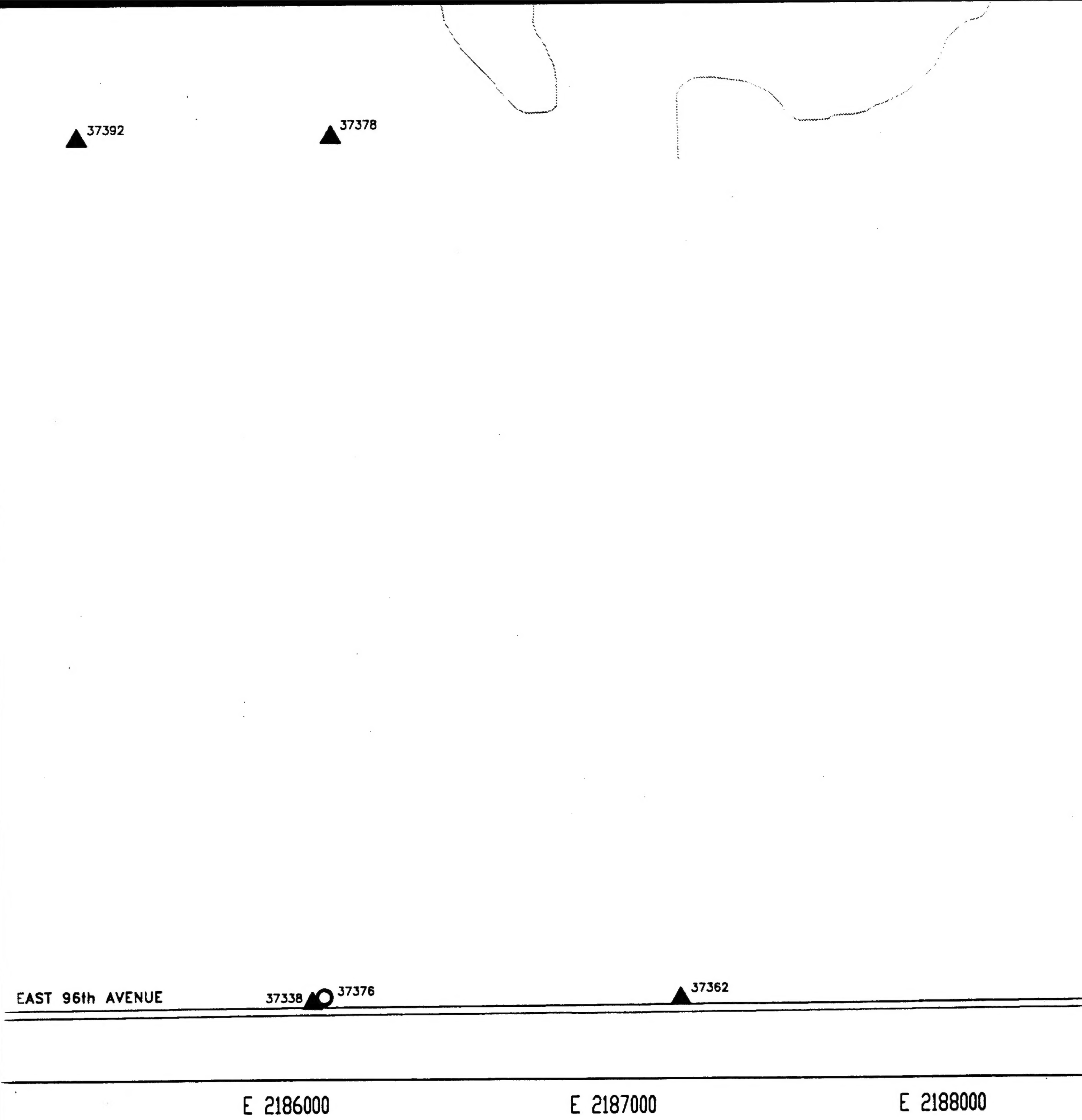
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E 2188000

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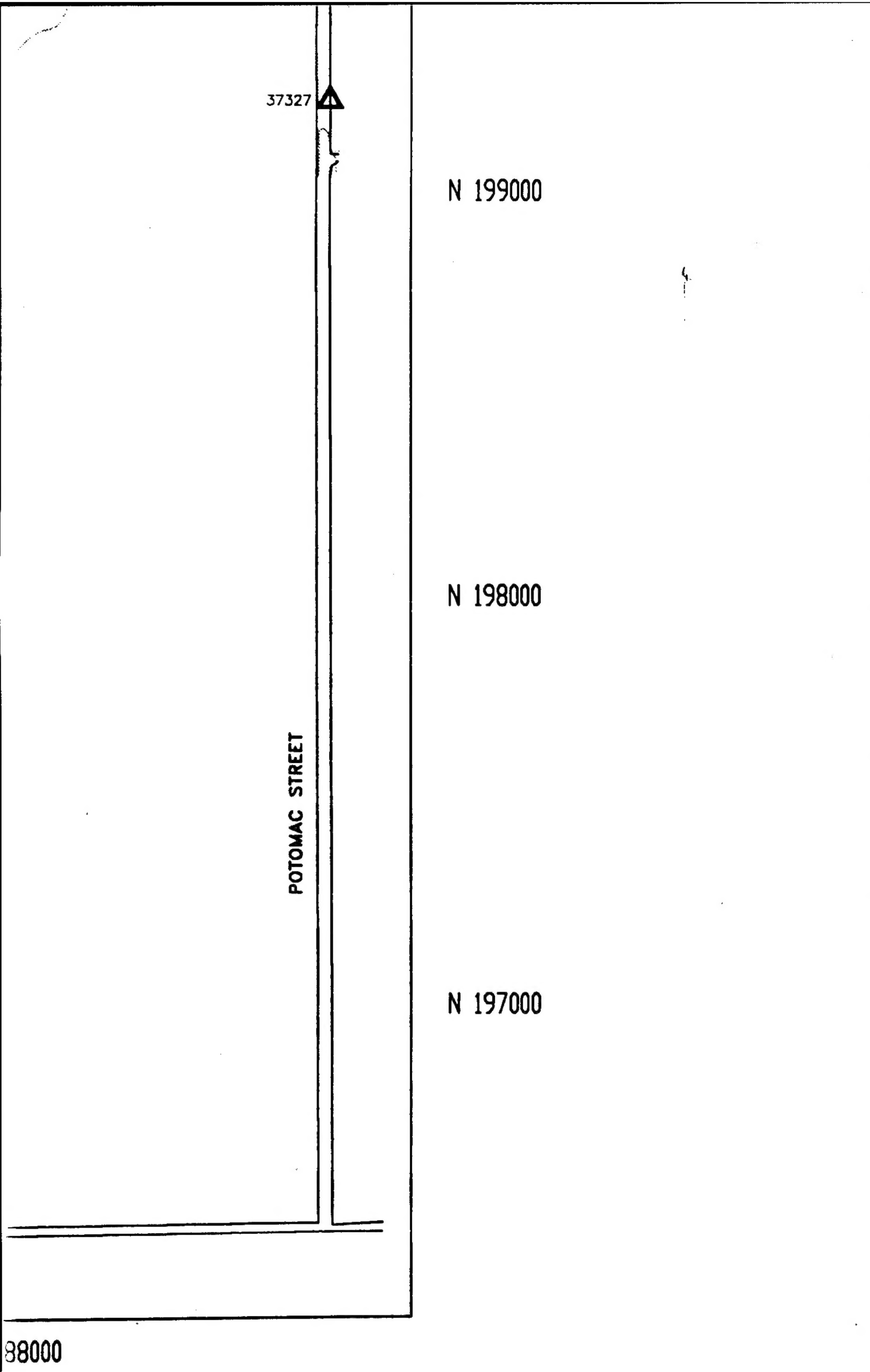

Prepared for:

U.S. Army Progr
for Rocky Mount

Commerce City,

PLATE 2

Sampling Locatio

Prepared by: Hc
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Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Commerce City, Colorado

PLATE 2 24A

Sampling Locations

Prepared by: Harding Lawson
Associates